Jet Propulsion Laboratory
California Institute of Technology

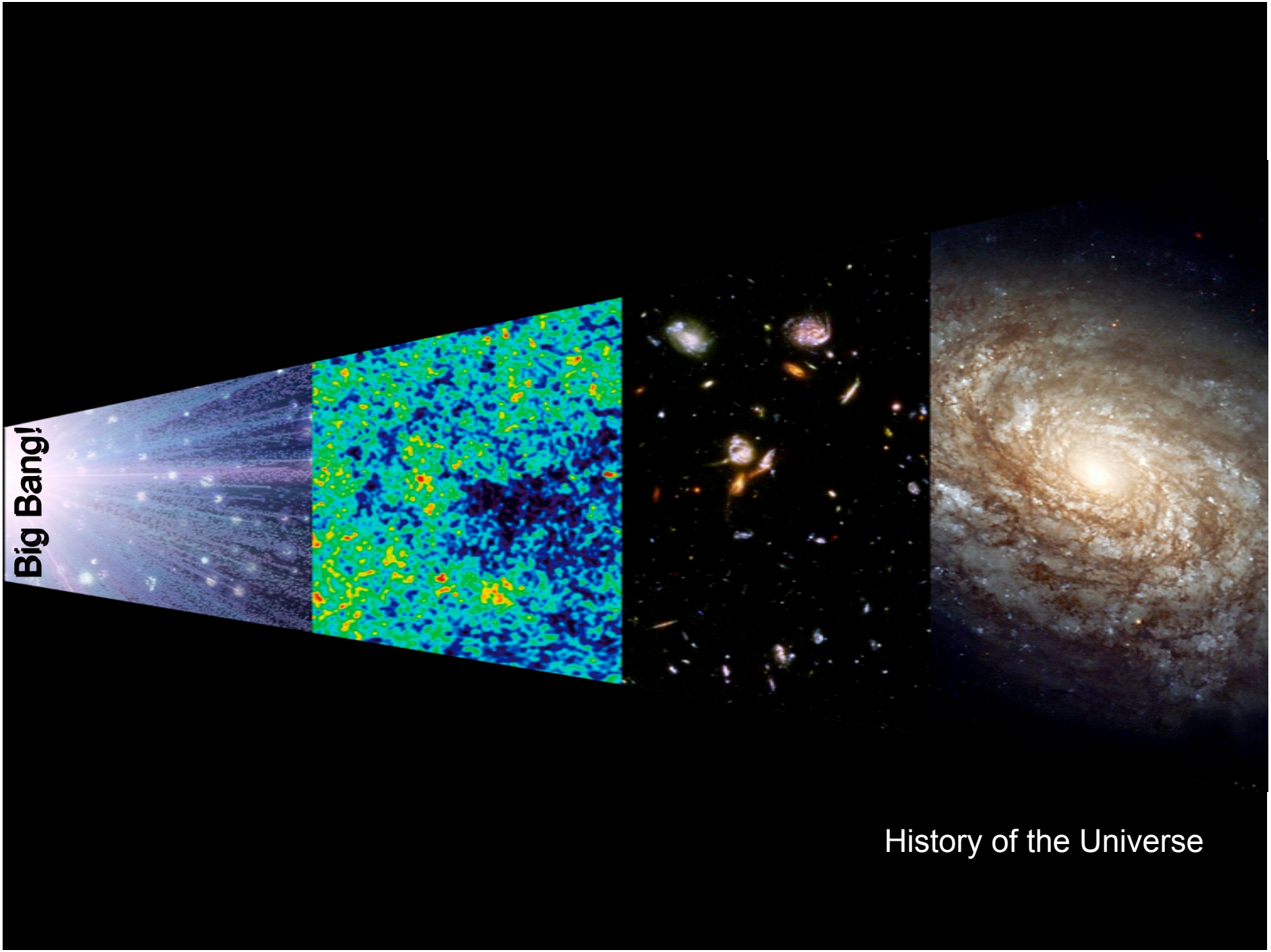
Curiosity's Landing on Mars & the Future of Space Exploration

a presentation to the

Georgia Institute of Technology

29 August 2012

Charles Elachi, Director
NASA Jet Propulsion Laboratory
California Institute of Technology


Big Bang!
History of the Universe


Five Interacting Galaxies

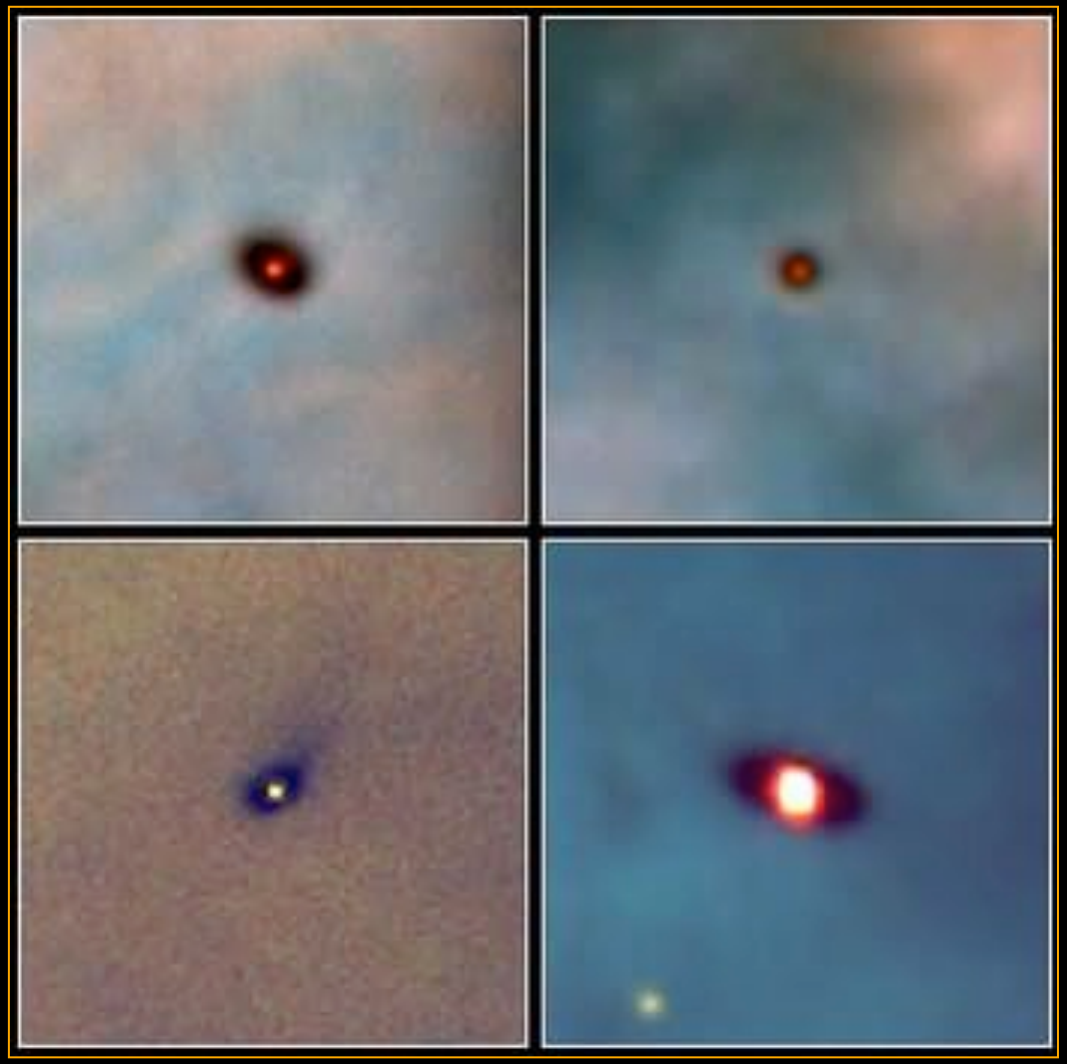

Spiral Galaxy
Composite: Spitzer, Hubble, Chandra

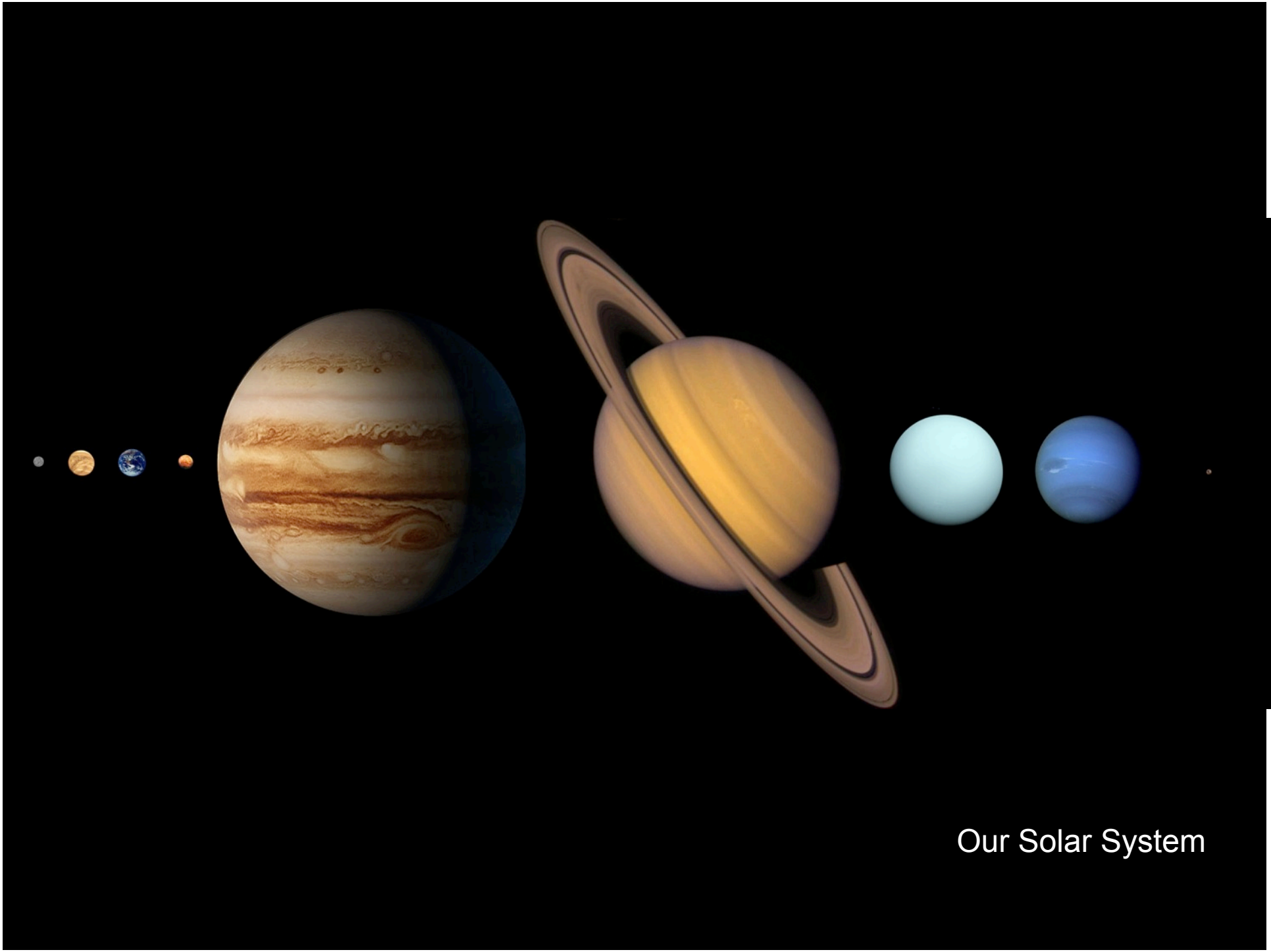
“Mountains” of Star Formation
Spitzer Space Telescope

Violent Galaxy
Hubble Space Telescope

Formation of Extra-Solar Disks

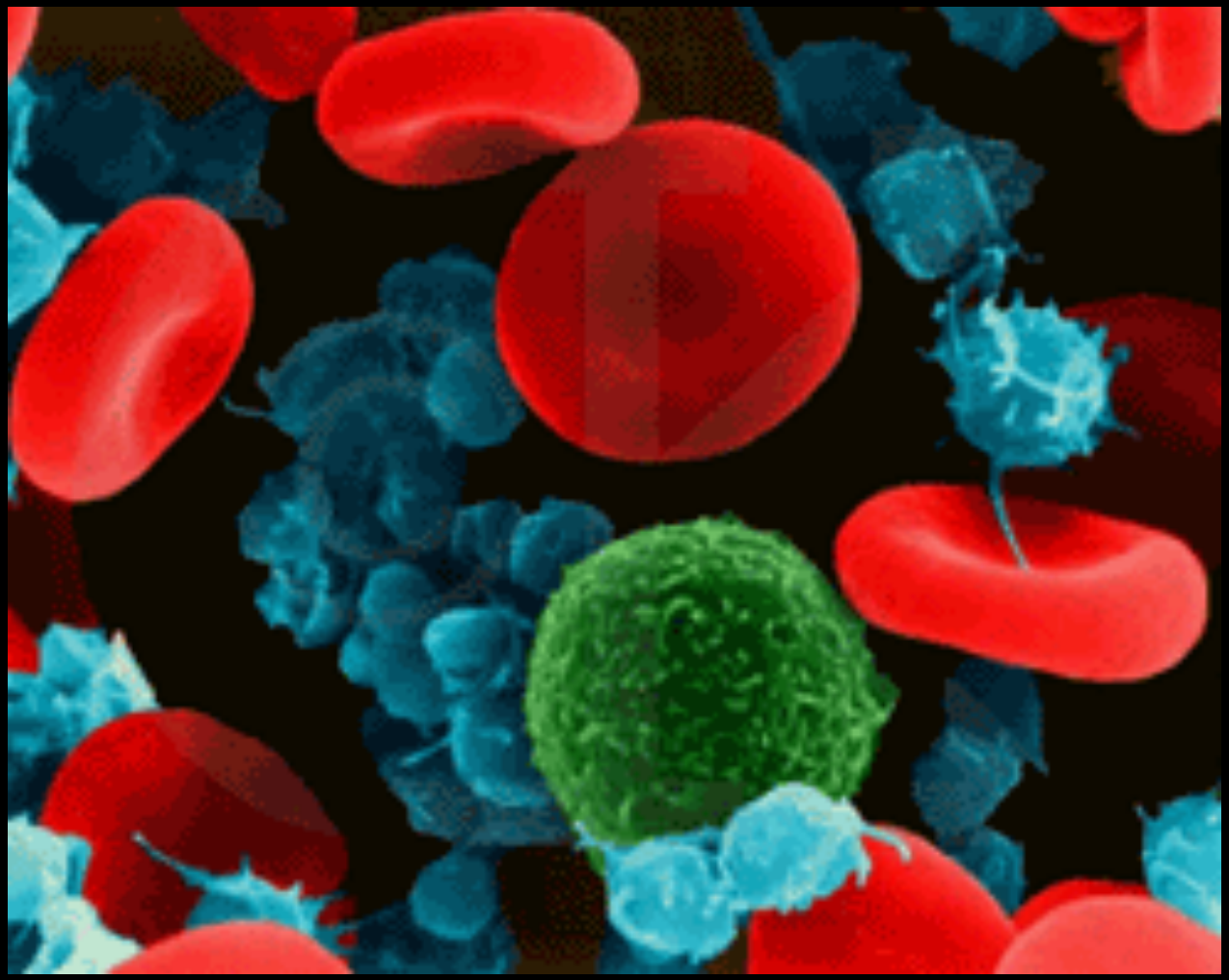
Hubble Space Telescope





Our Solar System


A Planet Friendly to Life



Self-replicating Molecules Lead to Cells and Life





3.8 Billion Years of Evolution Produced….






…Georgia Tech!

Kepler Exoplanet Results

First Definitive Detection of a Circumbinary Planet

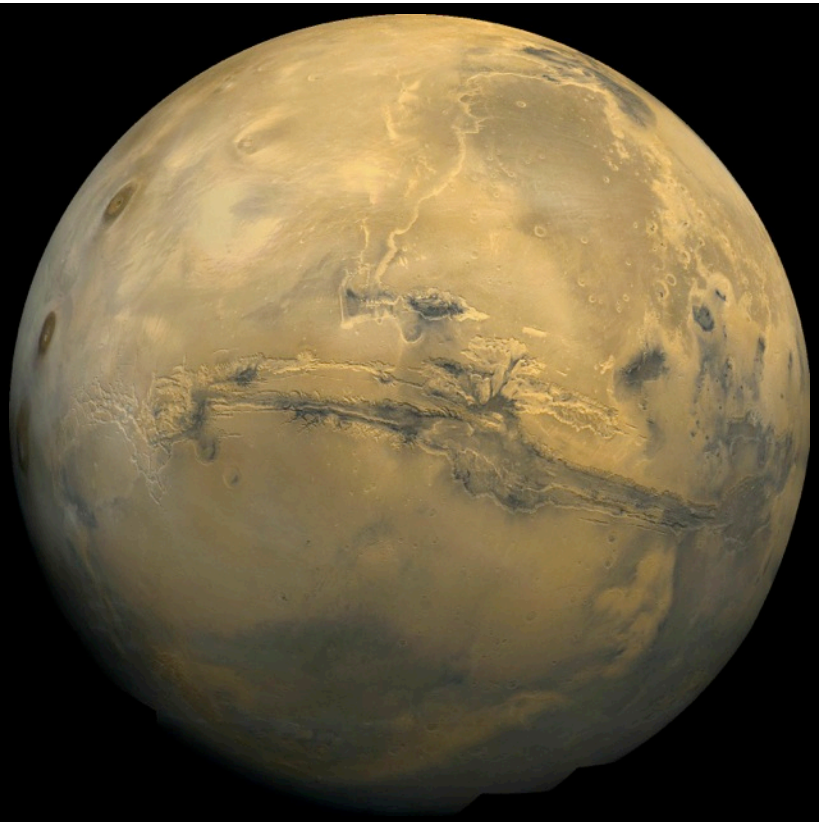
Kepler-16b Nicknamed “Tatooine”

2326 planet candidates found

74 planets confirmed as real

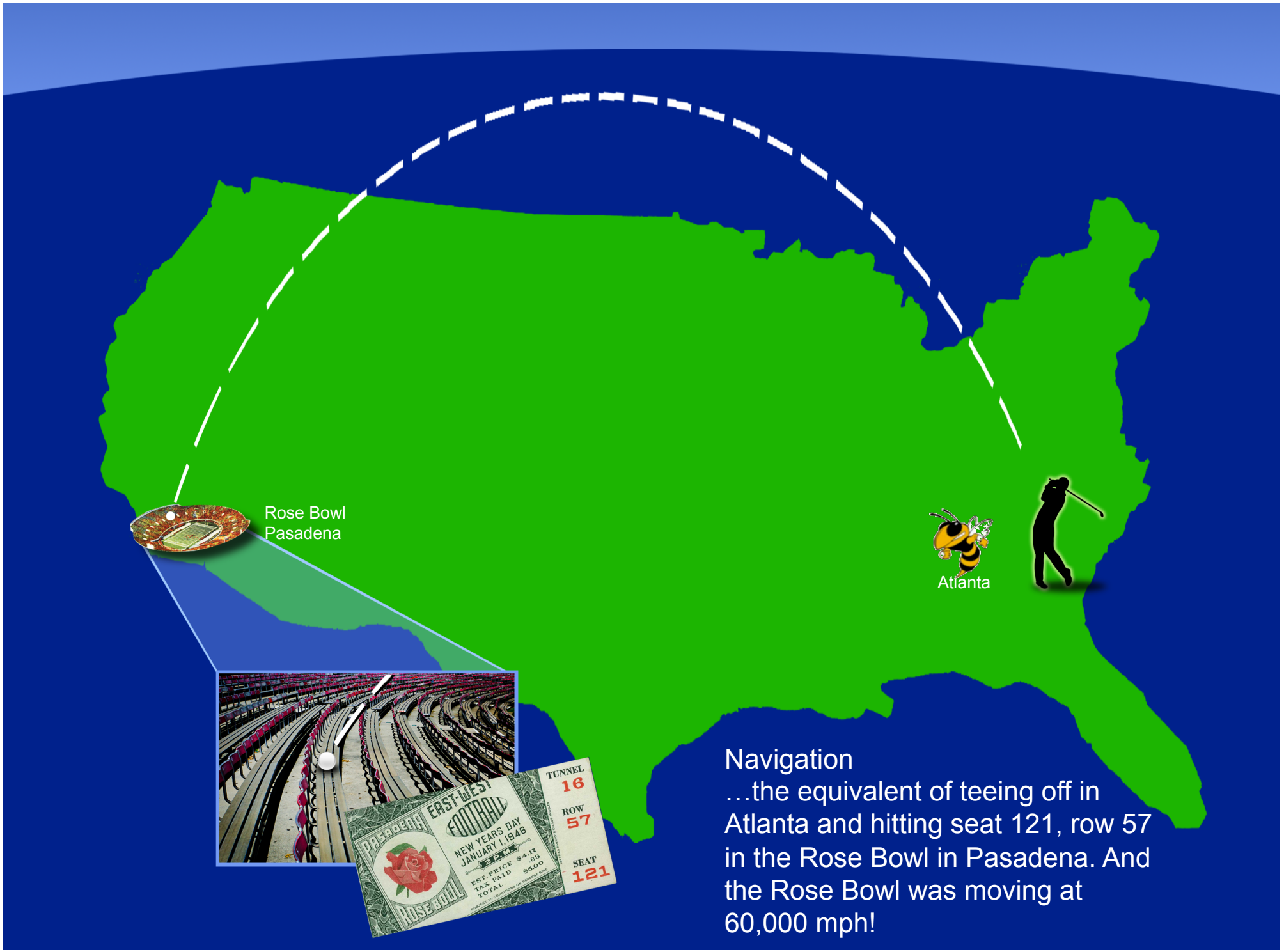
> 300 multiple planet systems with > 800 planets

Traveling 100 Million Miles to Mars



Navigation

After traveling 450 million kilometers, the rover *Curiosity* arrived at Mars within 2 kilometers of its intended landing site…



Navigation
…the equivalent of teeing off in Atlanta and hitting seat 121, row 57 in the Rose Bowl in Pasadena. And the Rose Bowl was moving at 60,000 mph!

Challenges of Space Exploration: Environmental

Venus: 850°F

Earth: 70°F

Mars: —50°F

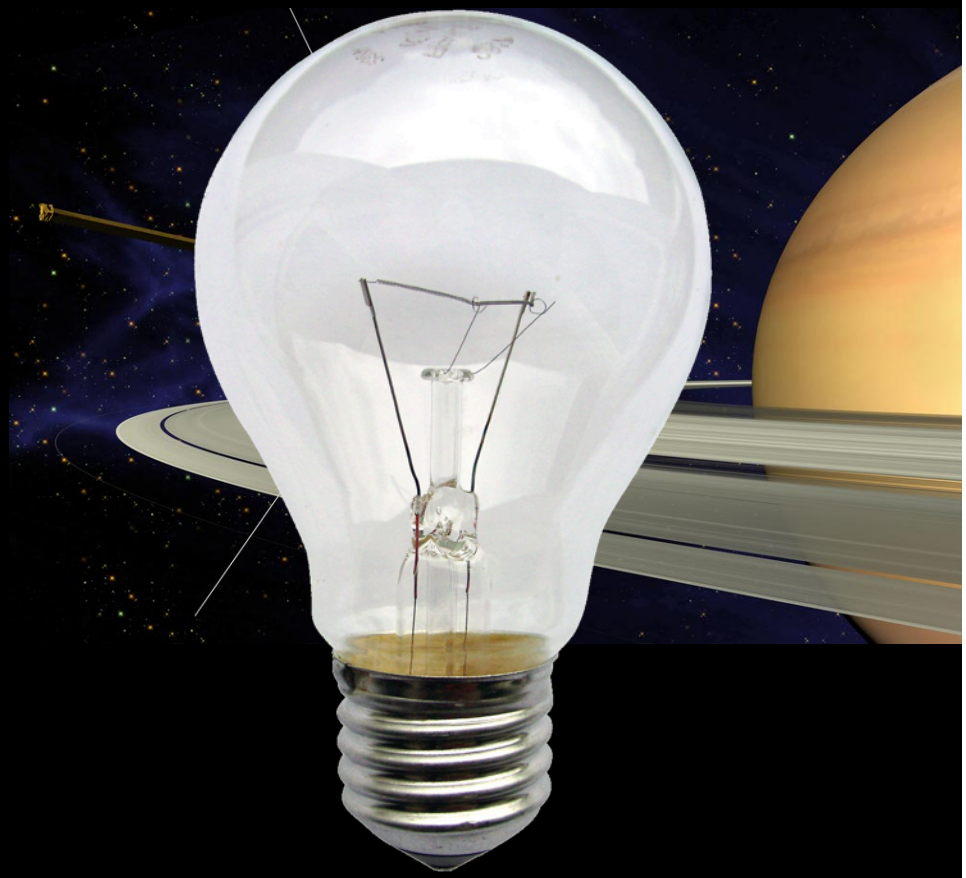
Saturn —300°F

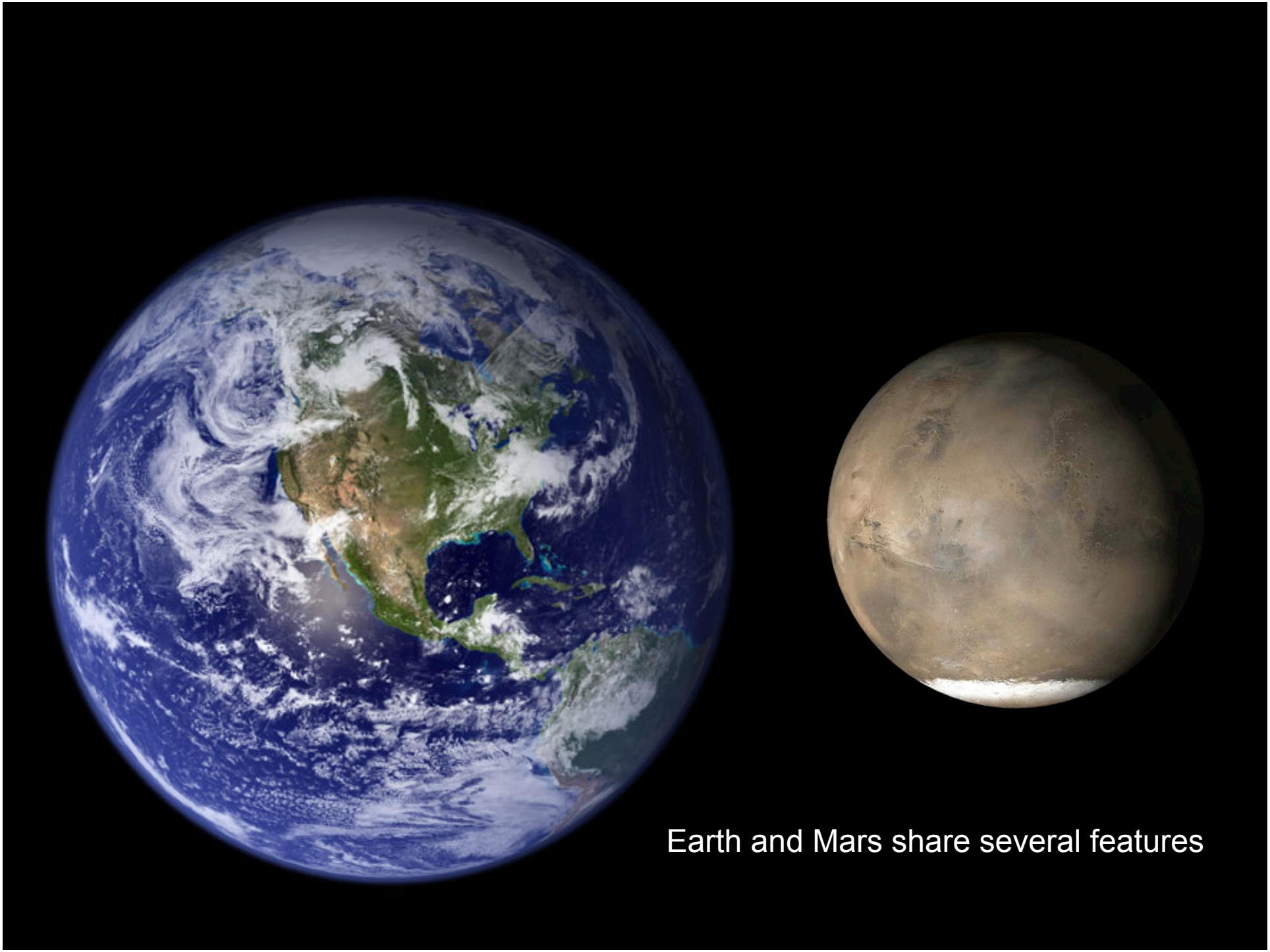
Challenges of Space Exploration: Telecommunications

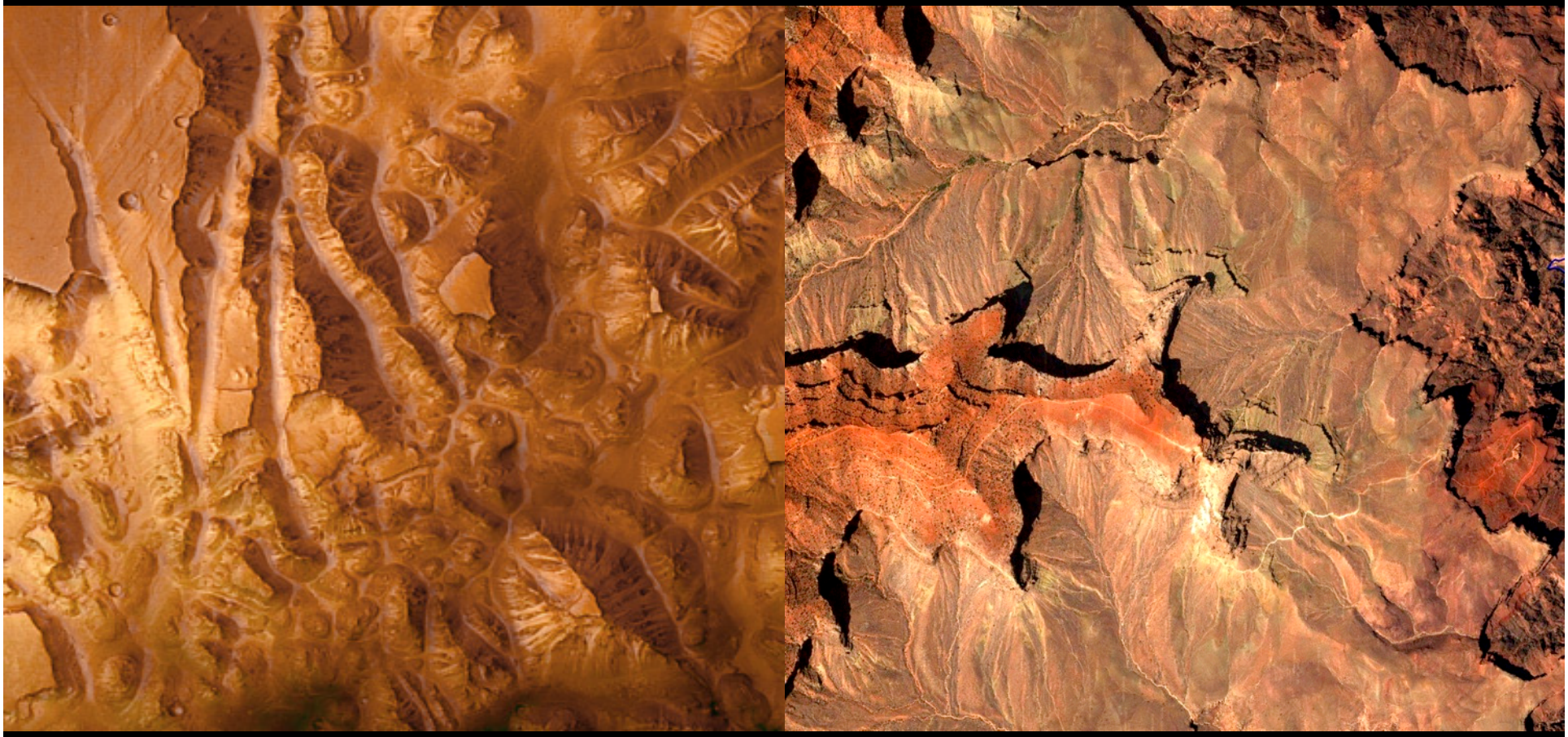
Transmitting one billion miles from Saturn using a 40 watt transmitter

0.00000000000000001 watt received at Earth

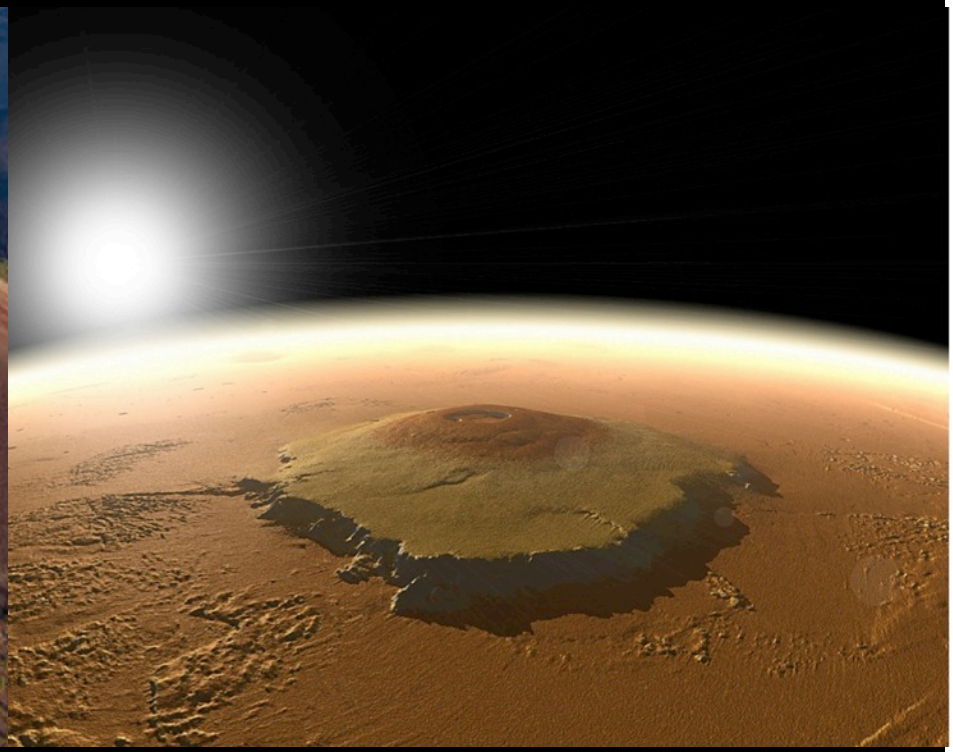
200,000,000,000,000,000,000 of these signals = 30 watt refrigerator light




Earth and Mars share several features

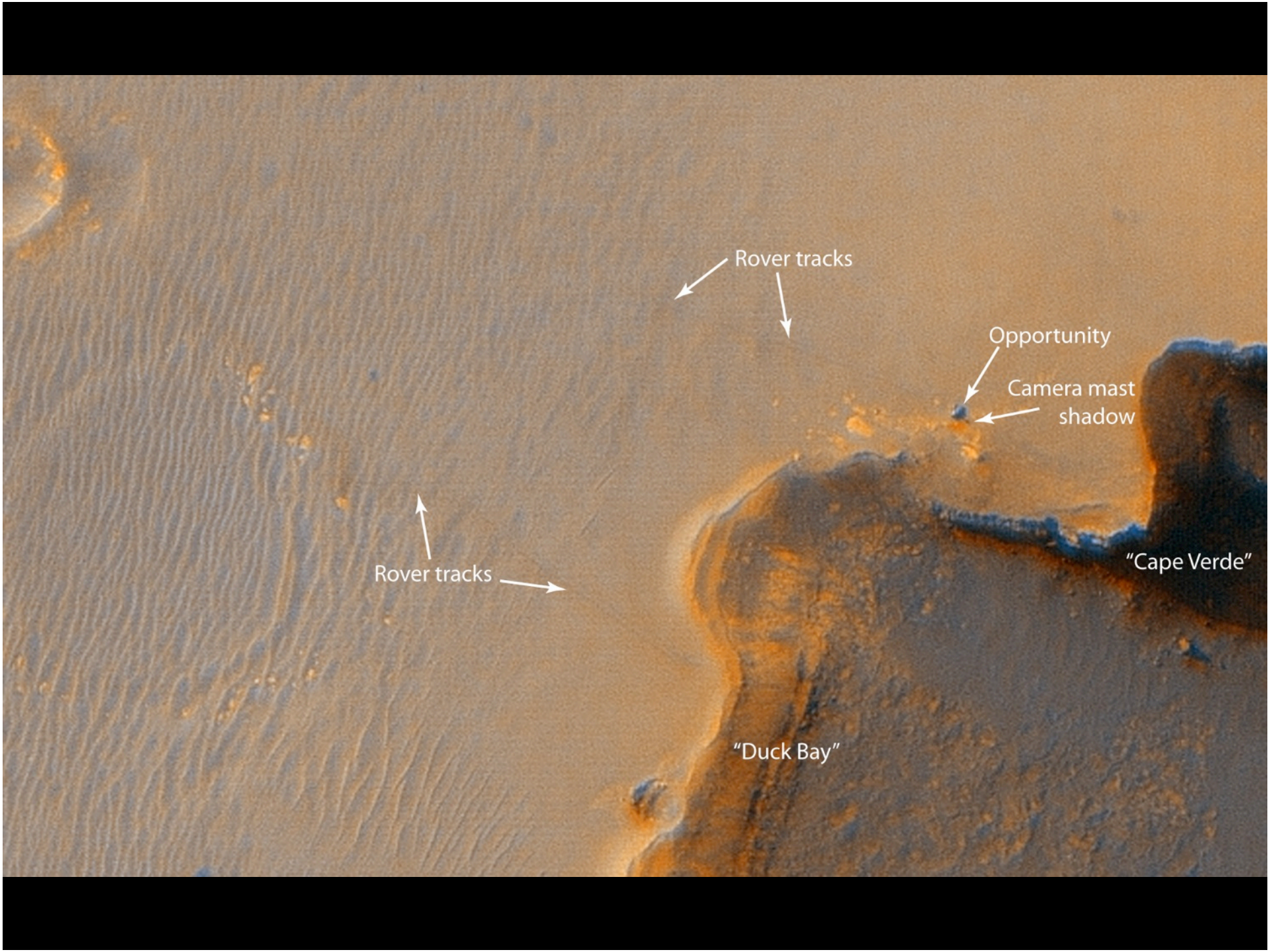


Grand Canyons

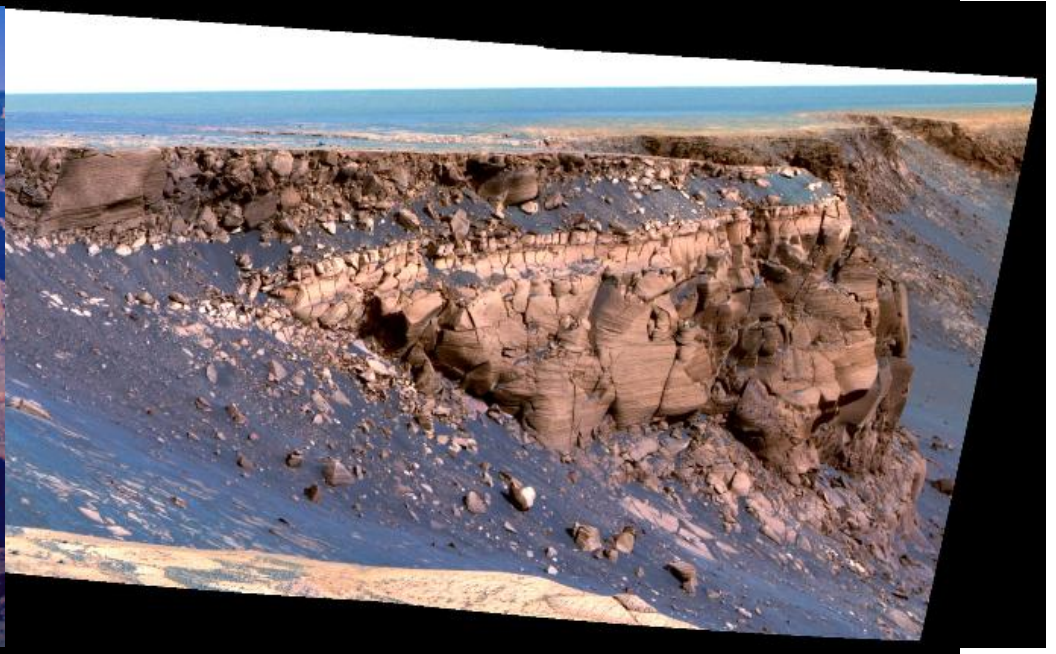


Great Volcanoes

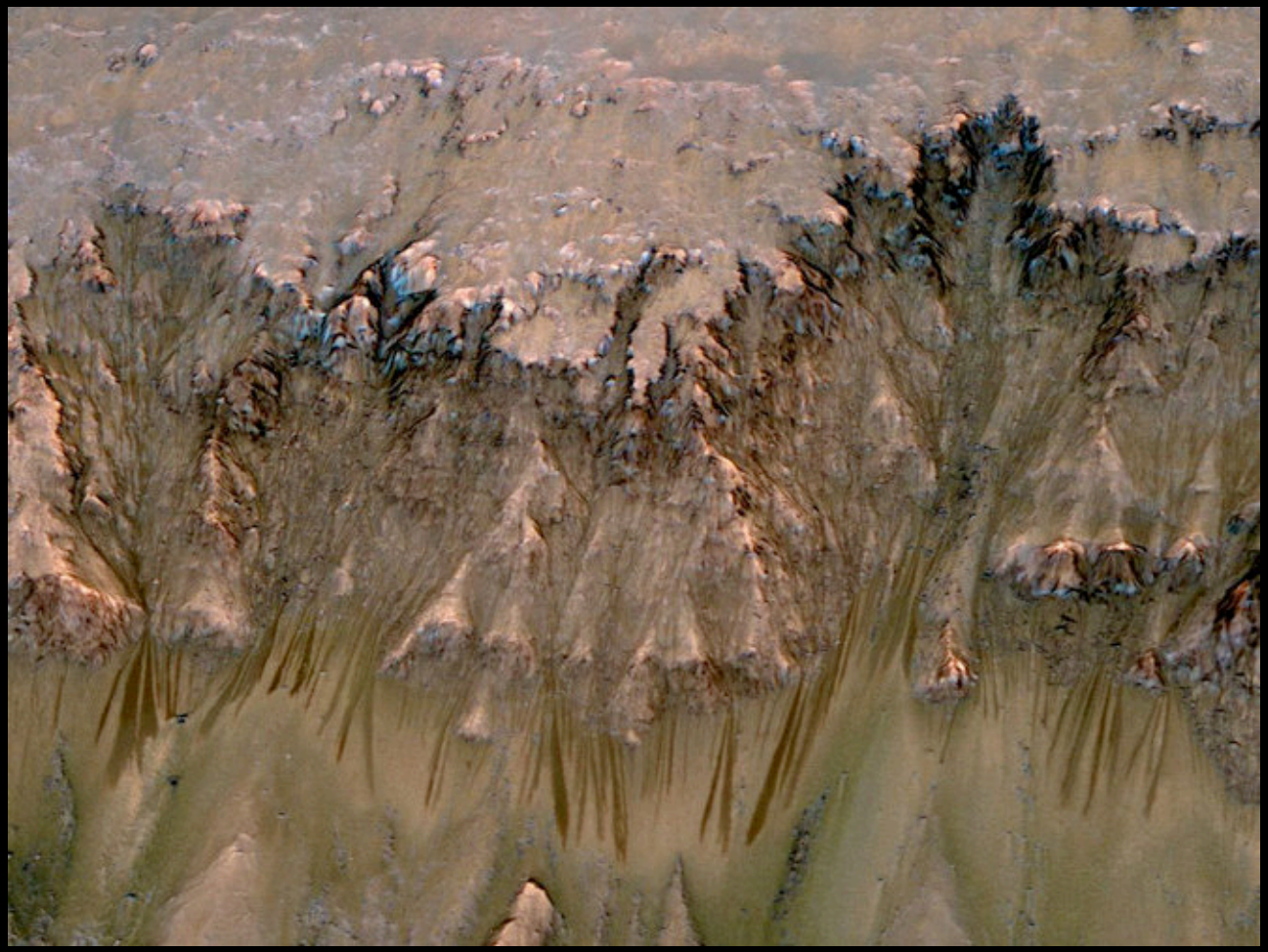
Geology


Rover tracks
Opportunity
Camera mast shadow
Rover tracks
"Cape Verde"
"Duck Bay"

Arizona’s Grand Canyon

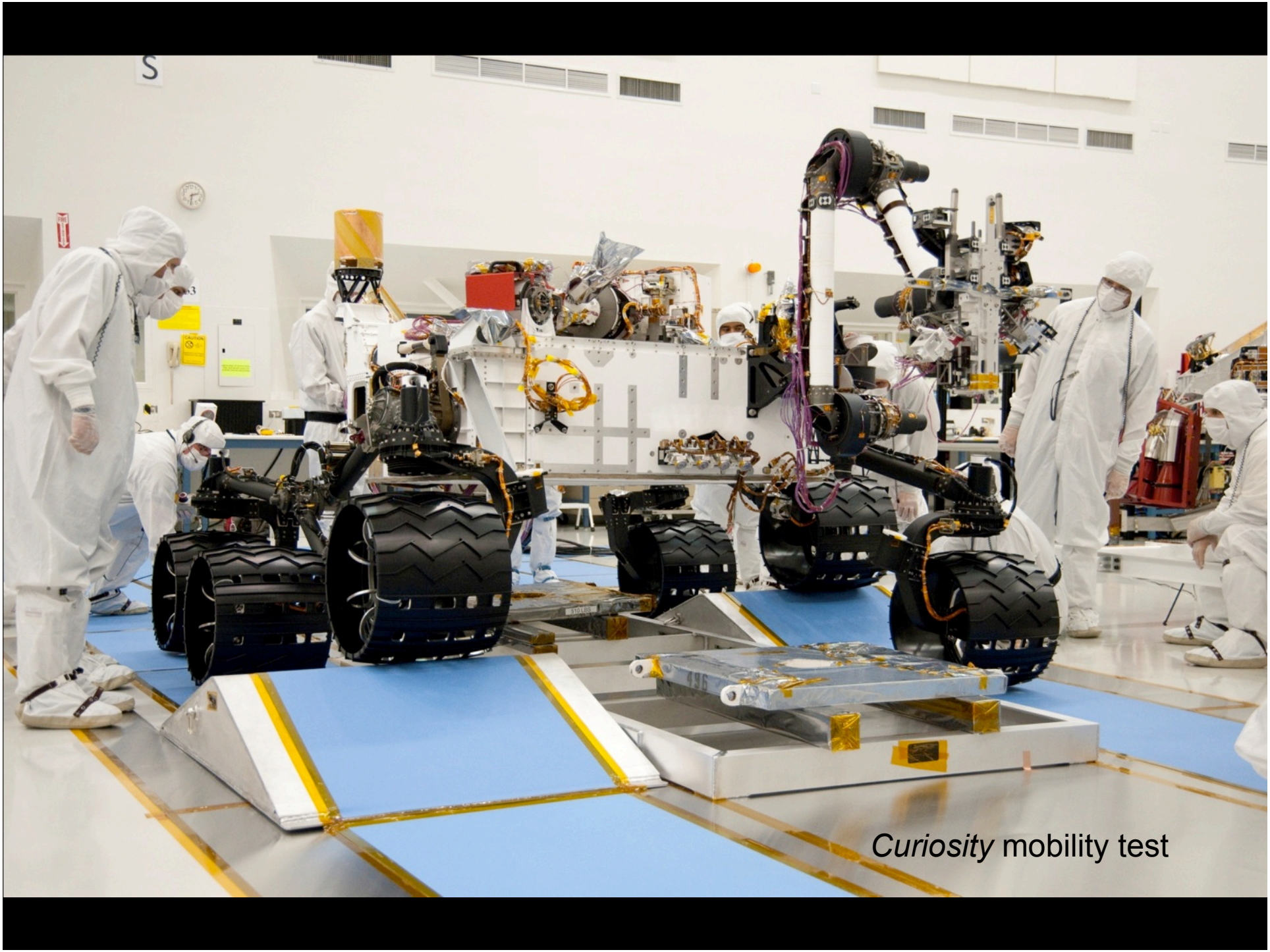


Mars’ Victoria Crater from *Opportunity*



Evidence of water on Mars
Mars Reconnaissance Orbiter

Three Generations of Rovers

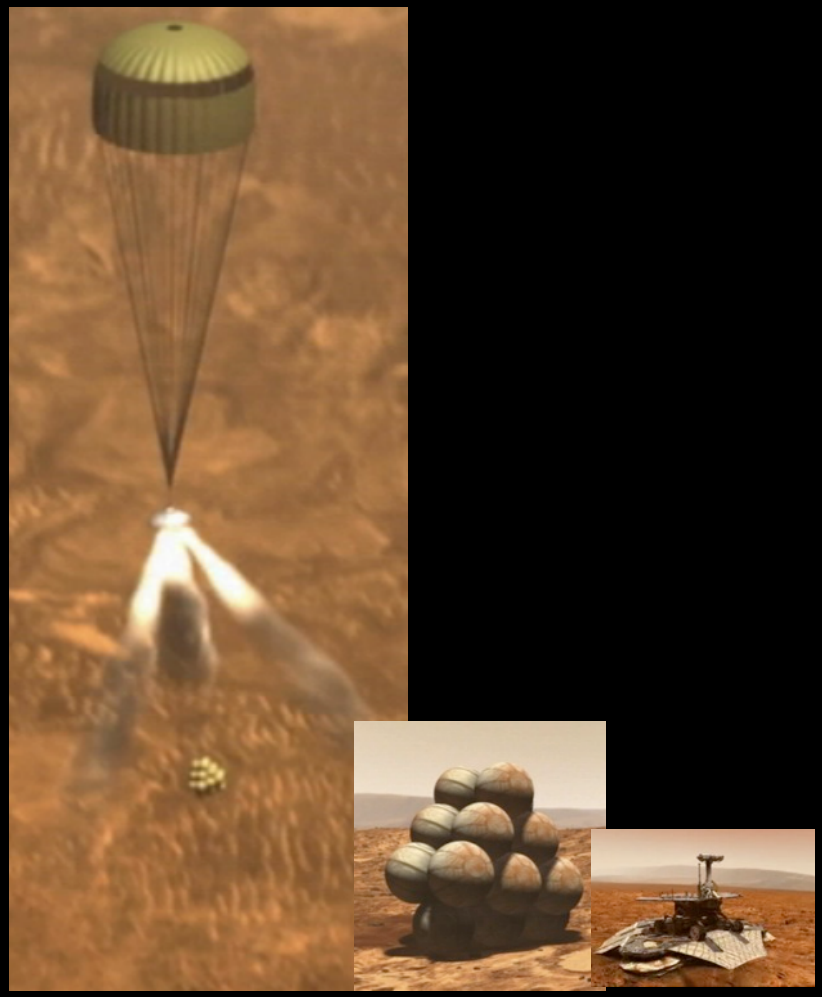


Curiosity mobility test

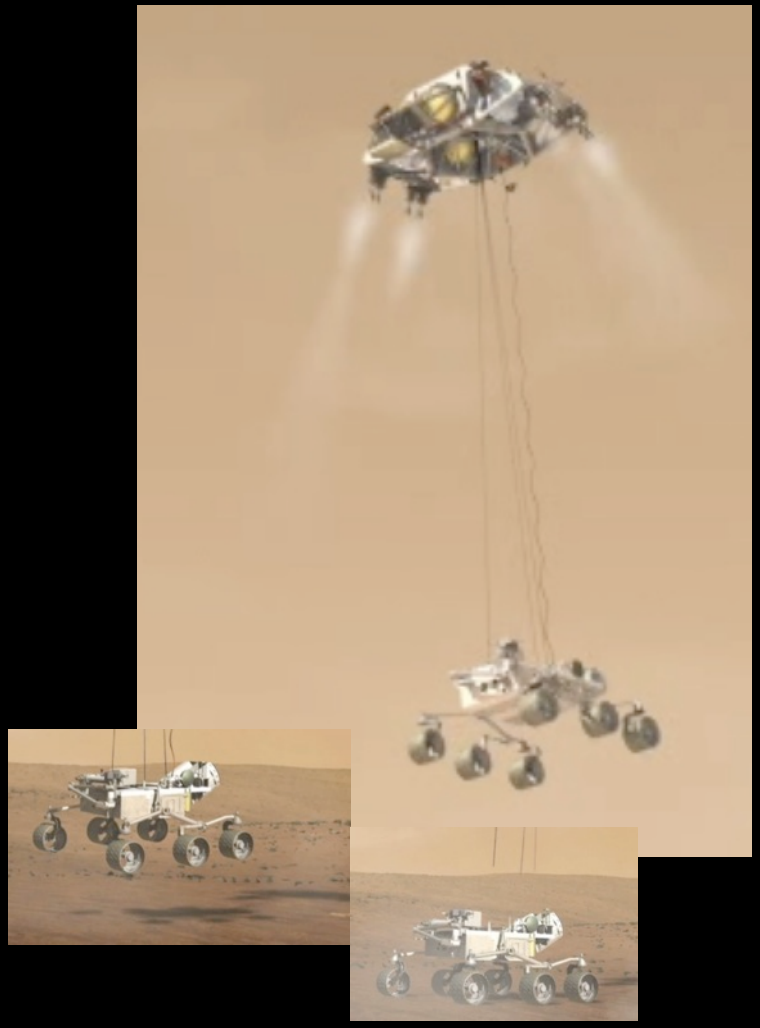
Early mobility testing of Mars Science Laboratory in JPL Mars yard

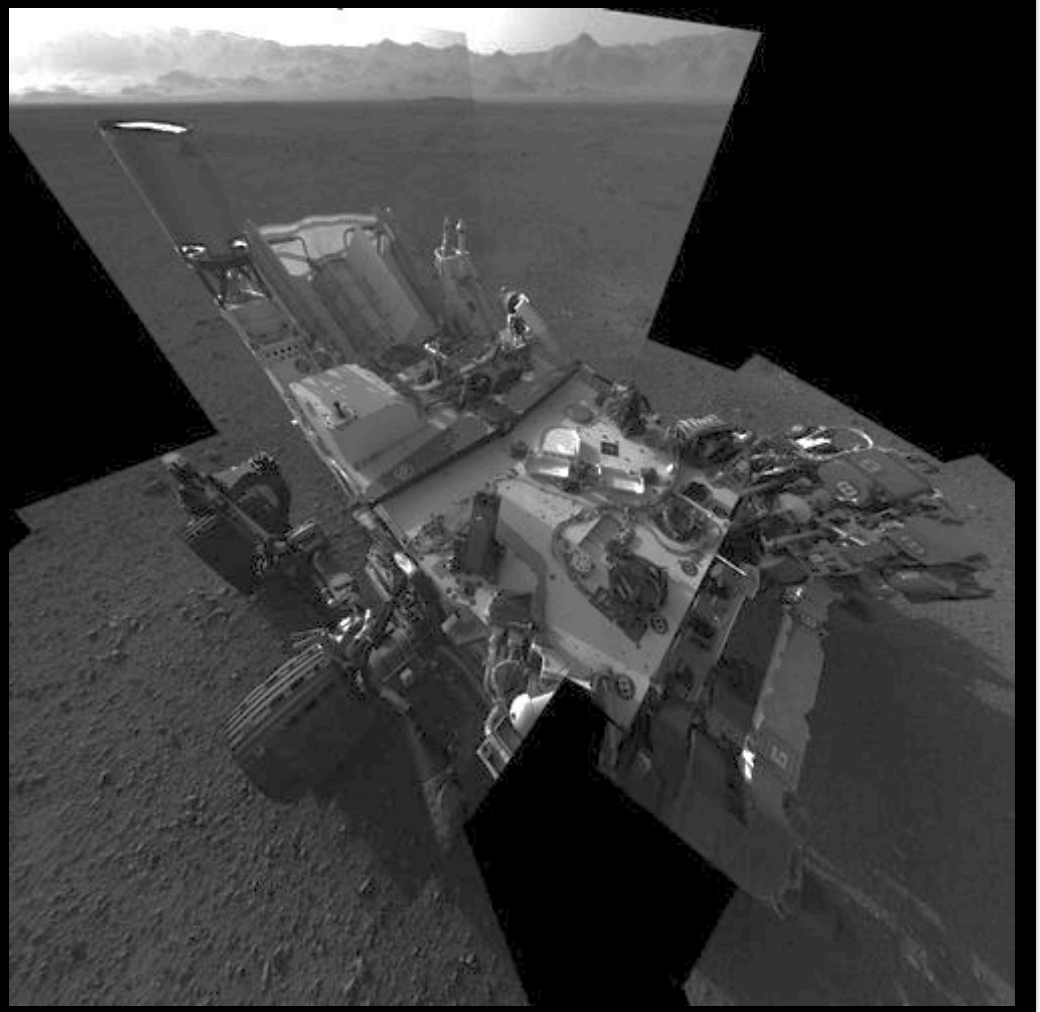
Entry, Descent, and Landing

MER

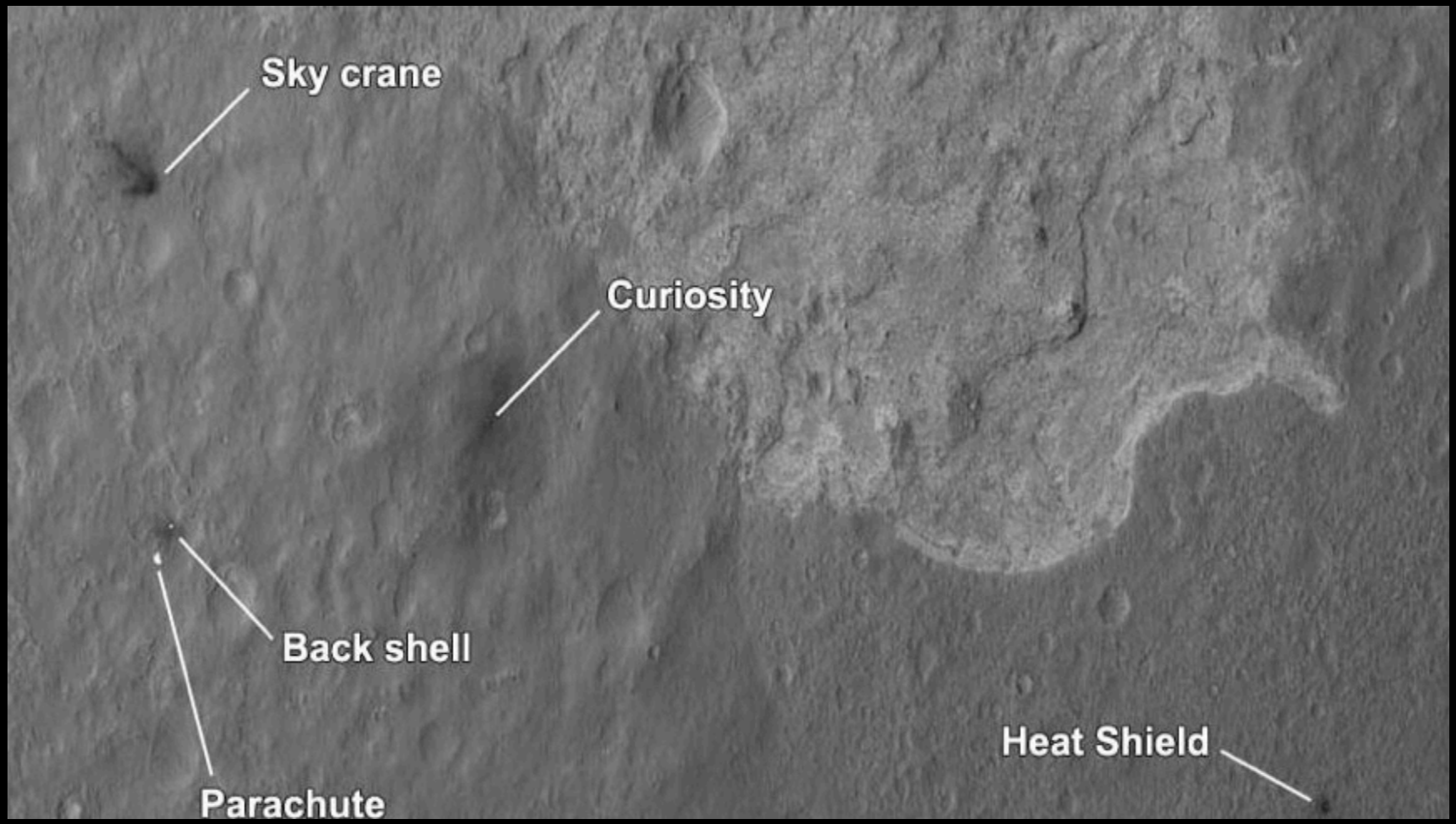


MSL



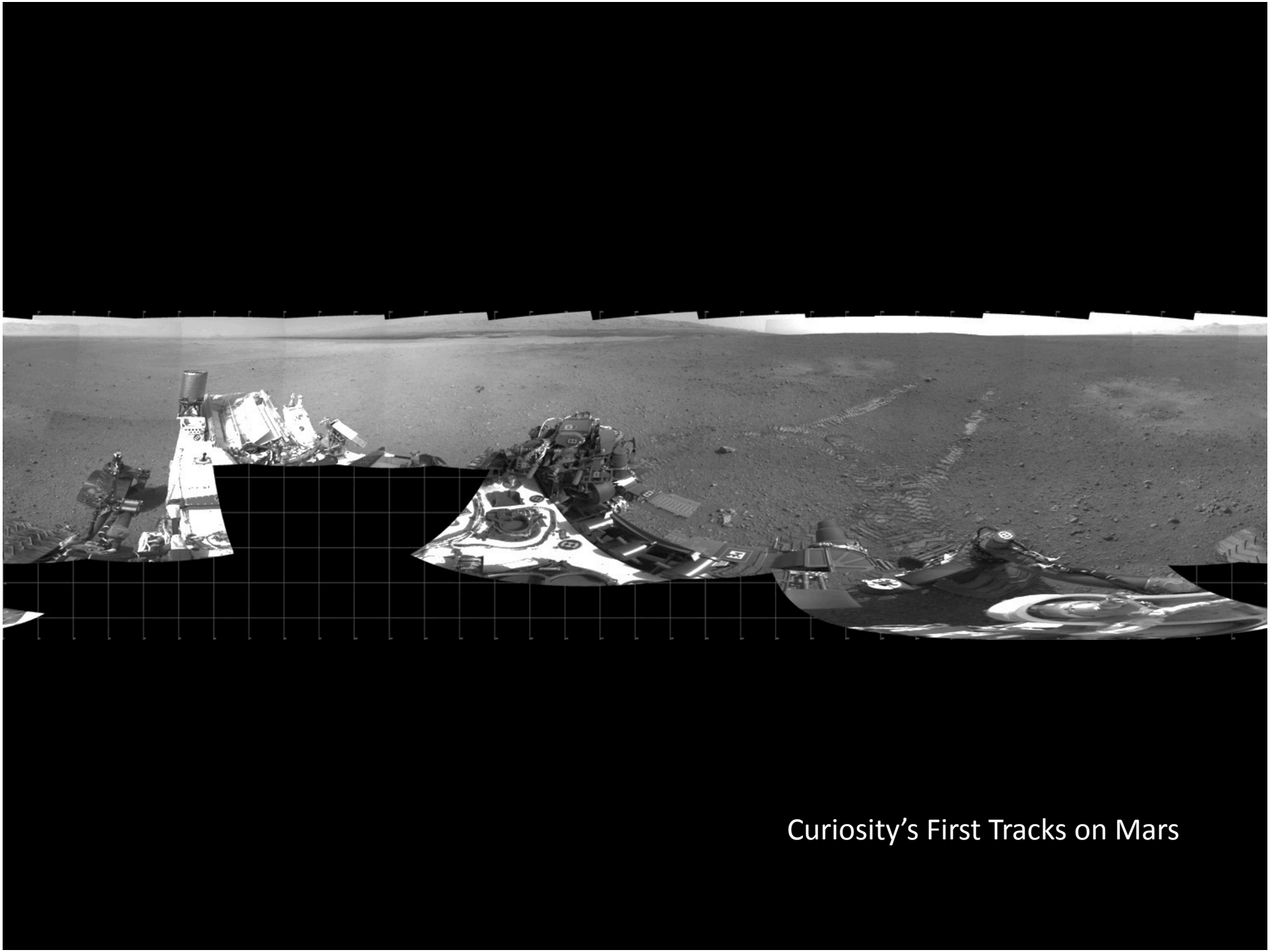


Curiosity – Mars Science Laboratory
Launched November 26, 2011
Landed August 5, 2012

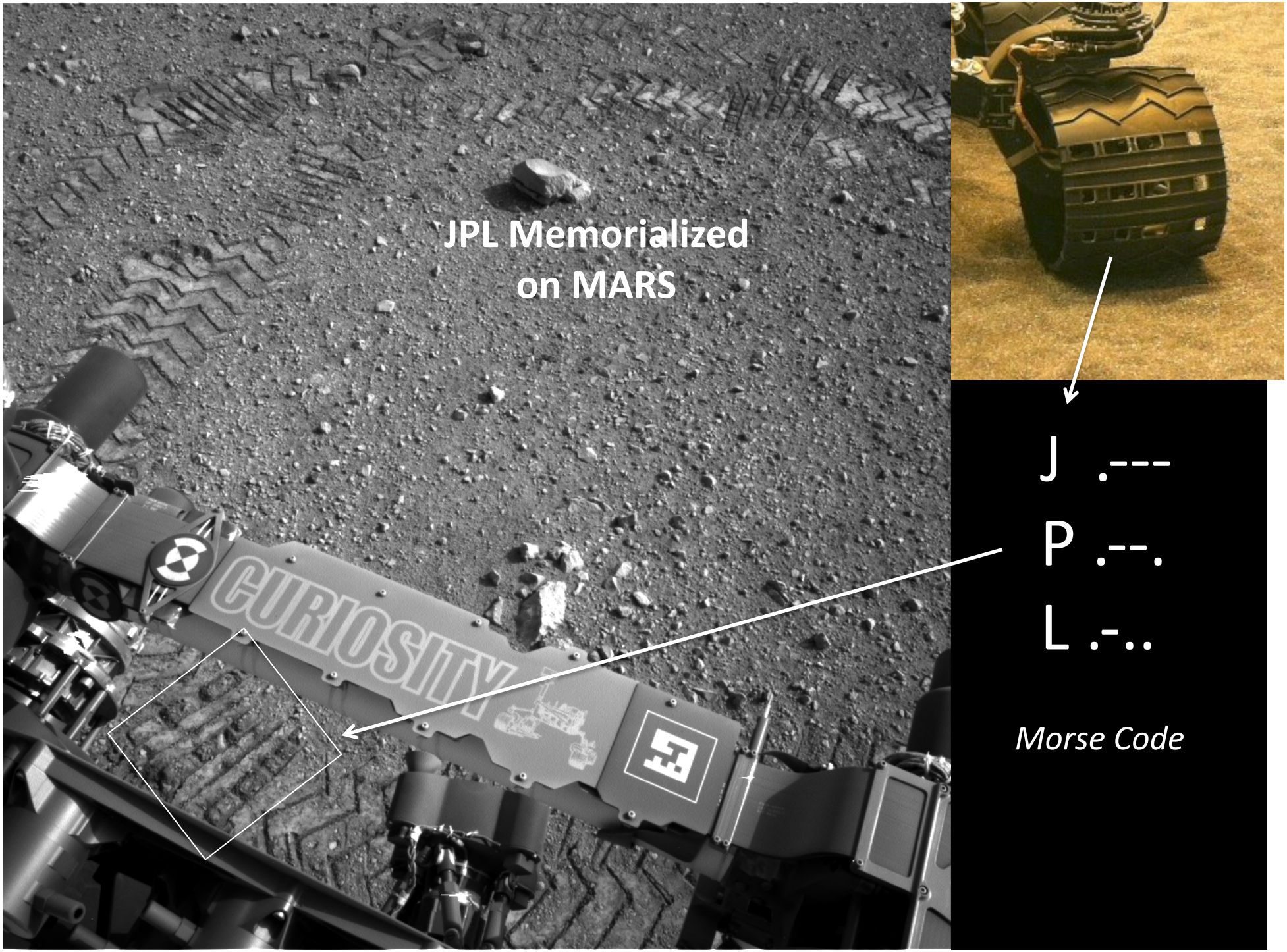


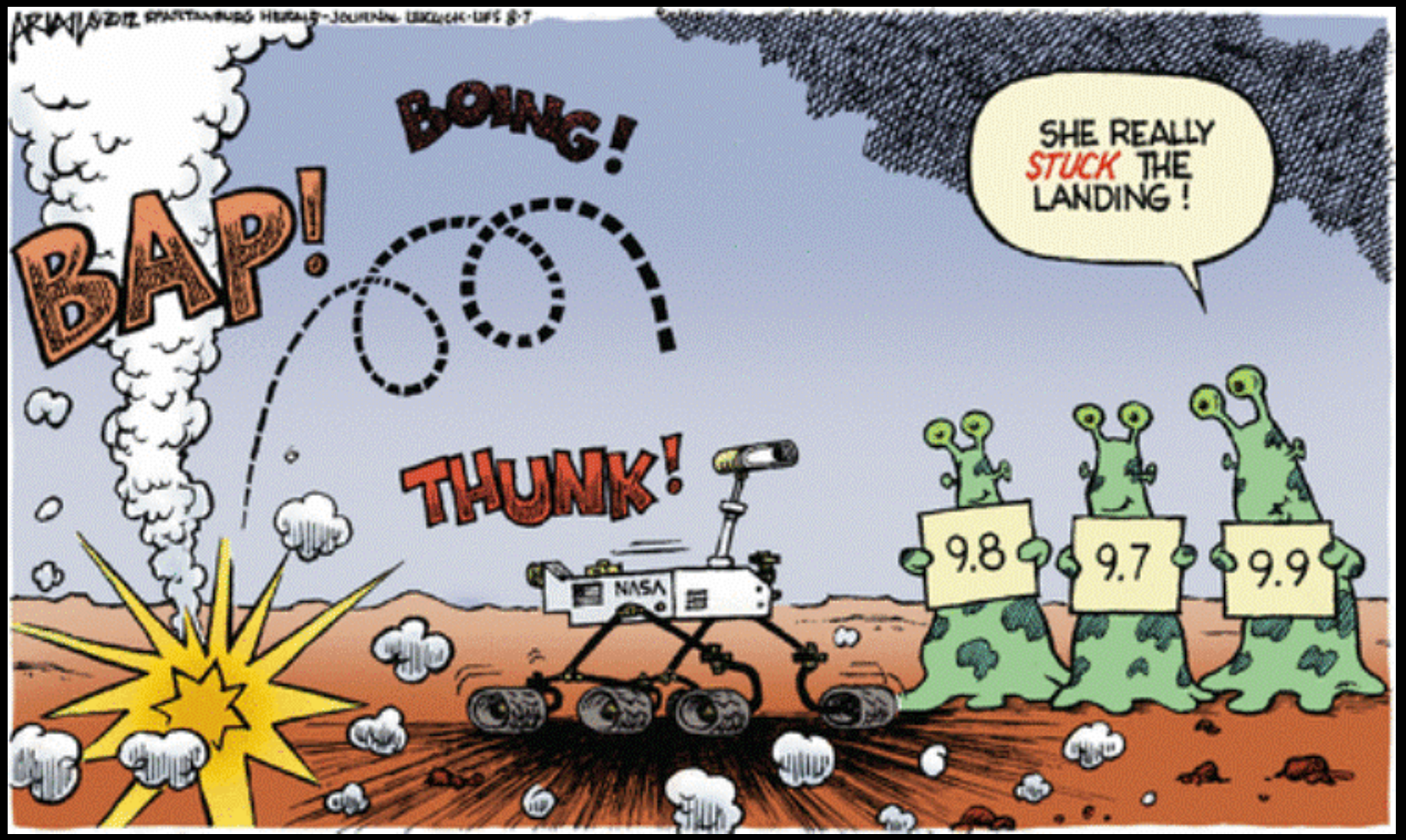
CSI: Mars

Curiosity’s New Home



Curiosity's First Tracks on Mars


JPL Memorialized
on MARS
CURIOSITY
J .---
P .--.
L .-..
Morse Code


BAP!
BOING!
THUNK!
SHE REALLY STUCK THE LANDING!
NASA
9.8
9.7
9.9

Mars Convention and Visitors Bureau
4 Red Rock Way
Aeolis Place, Gale Crater, Mars 43601-3712
Phone (813) 867-5309 Fax (813) 777-7777

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Pasadena, CA 91109

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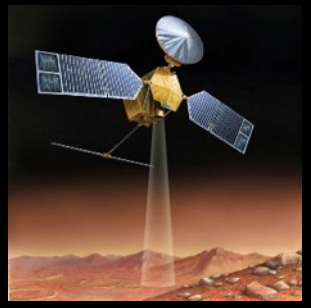
EVENT PARKING – GALE CRATER	$17.95
LITTERING	$99.00
TOTAL	$116.95

Make all checks payable to Mars Convention and Visitors Bureau

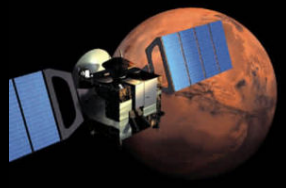
THANK YOU FOR YOUR BUSINESS!

Now: A continuous robotic presence on and in orbit around Mars

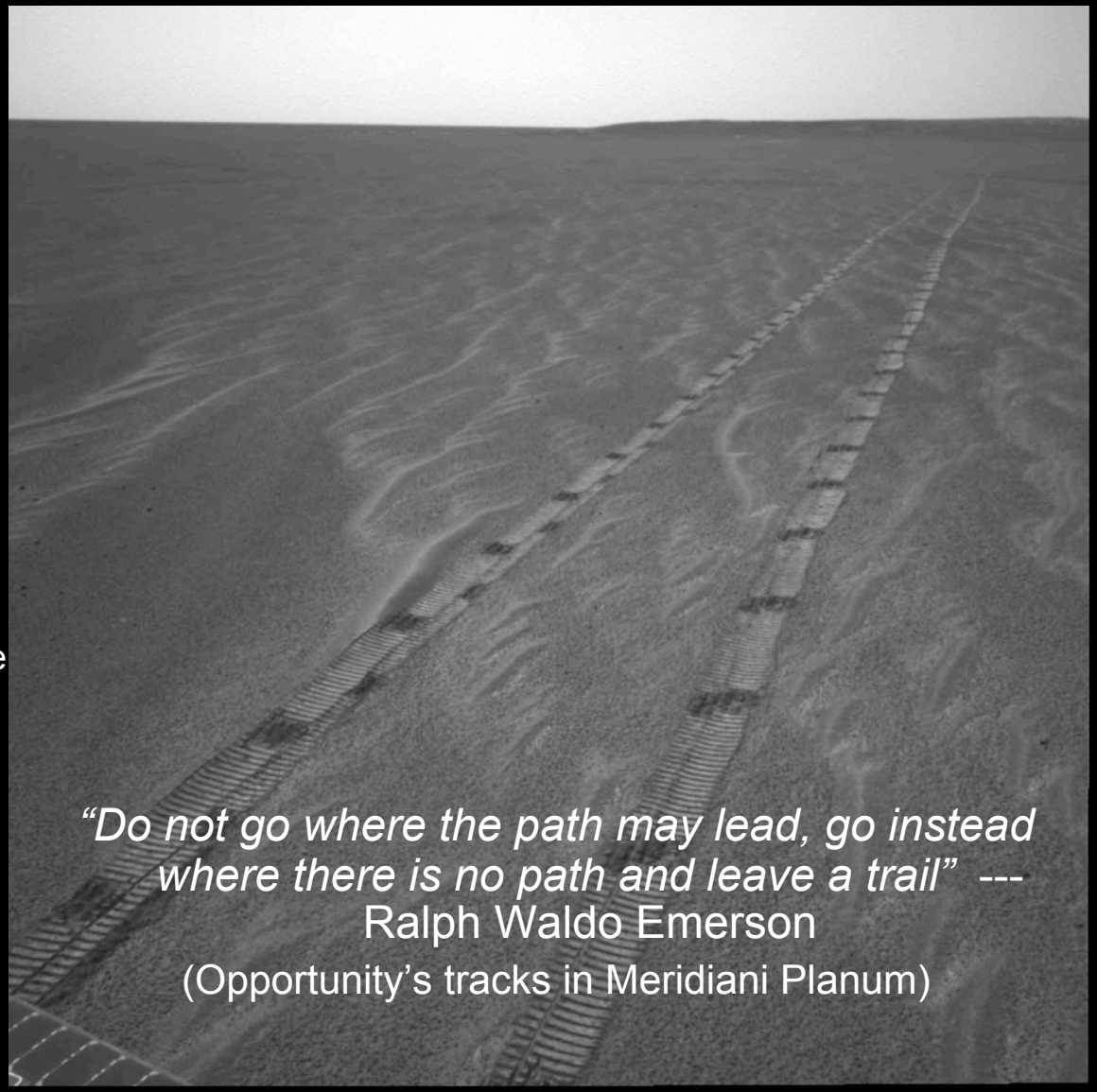
2001 Mars Odyssey



Mars Reconnaissance Orbiter

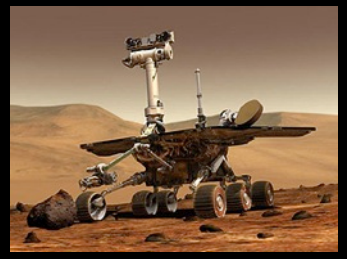


Mars Express (ESA)

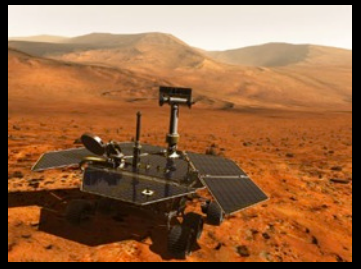


"Do not go where the path may lead, go instead where there is no path and leave a trail" --- Ralph Waldo Emerson

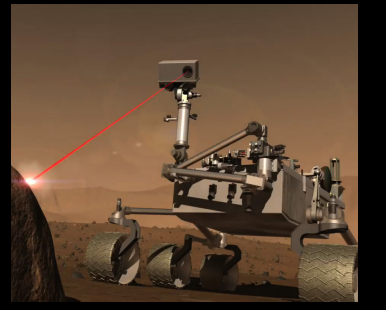
(Opportunity's tracks in Meridiani Planum)



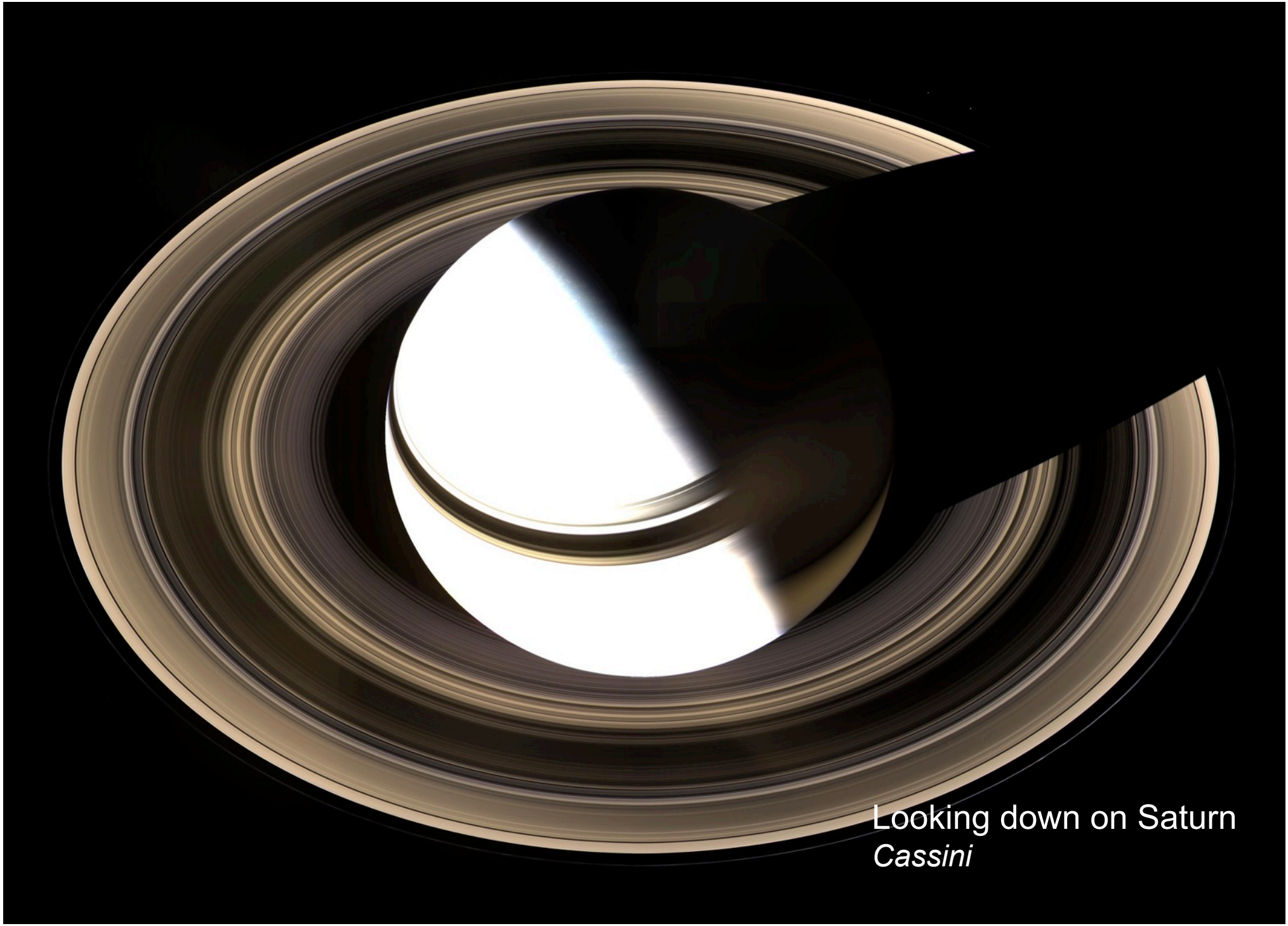
Spirit



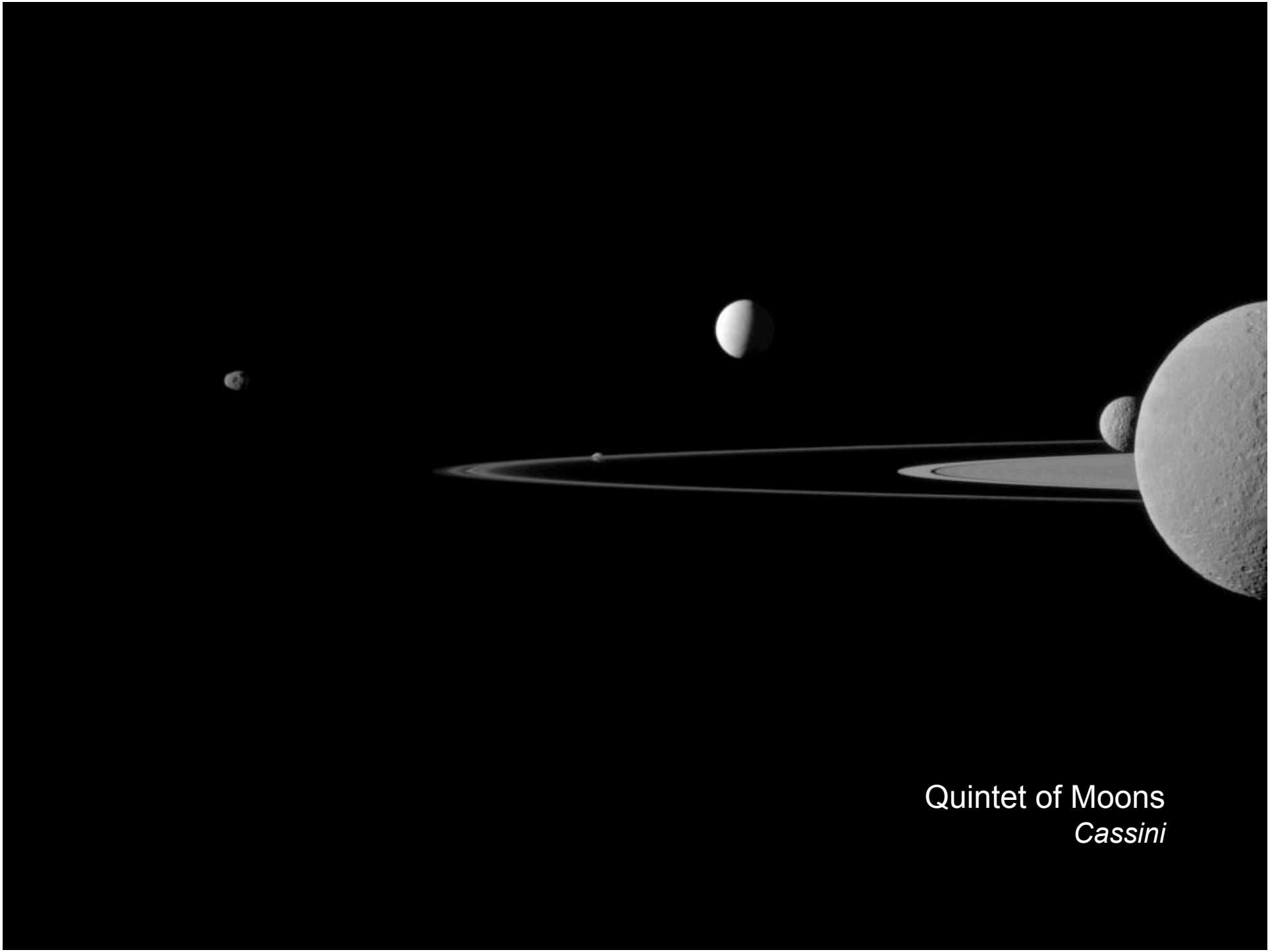
Opportunity



Curiosity



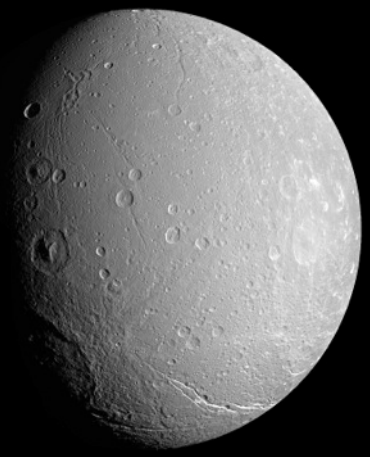
Looking down on Saturn
Cassini



Quintet of Moons
Cassini

Saturn's Scientifically Challenging Moons

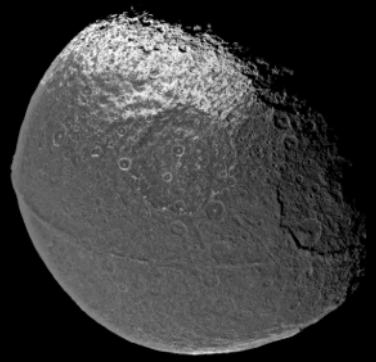
Cassini



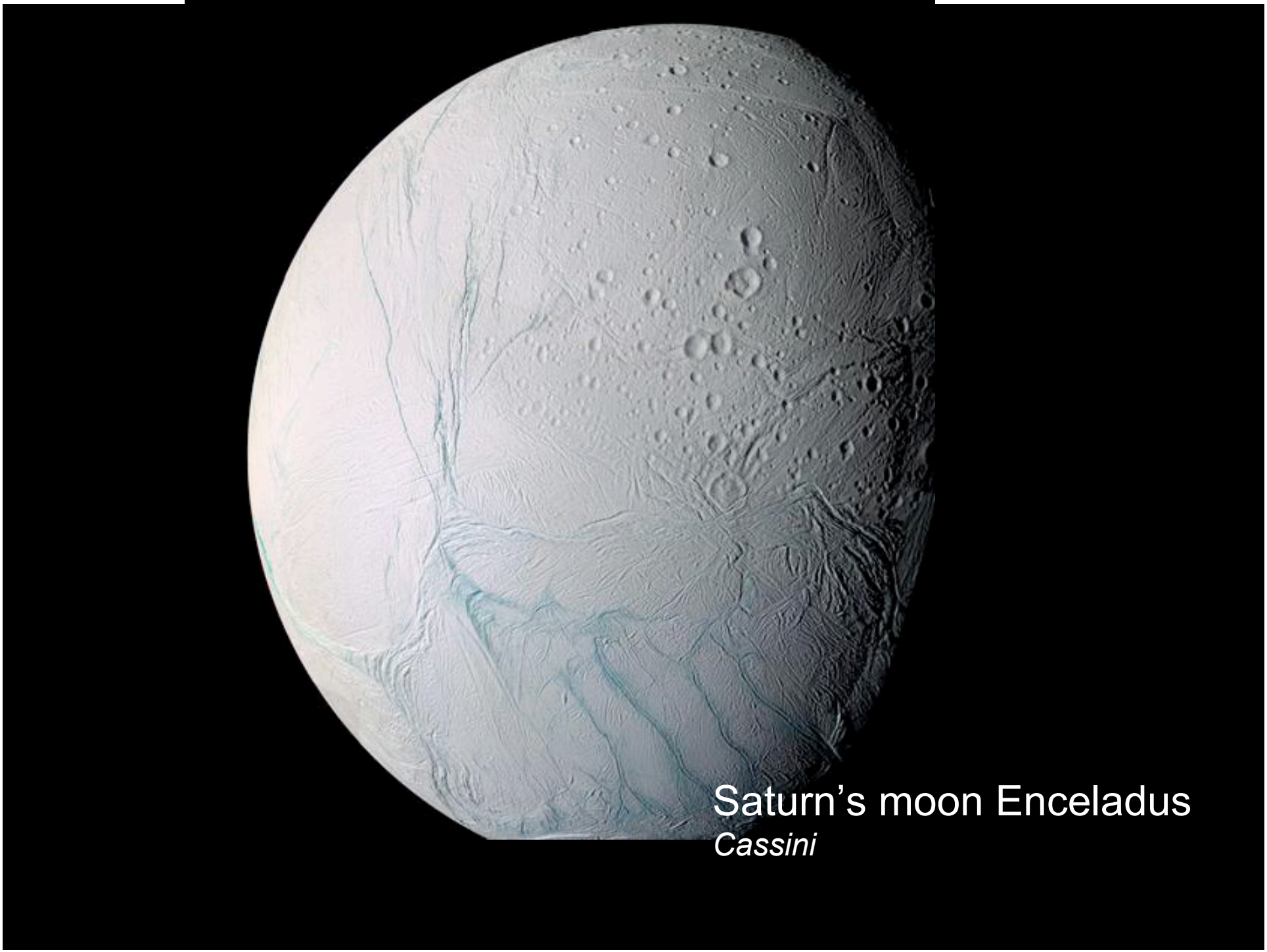
Dione

"Spongy" Hyperion

Icy Phoebe



Dark and light Iapetus, with equatorial ridge

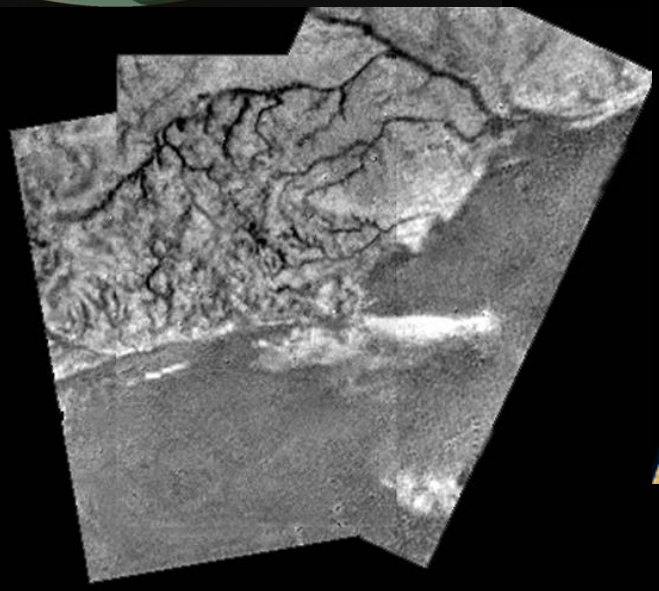


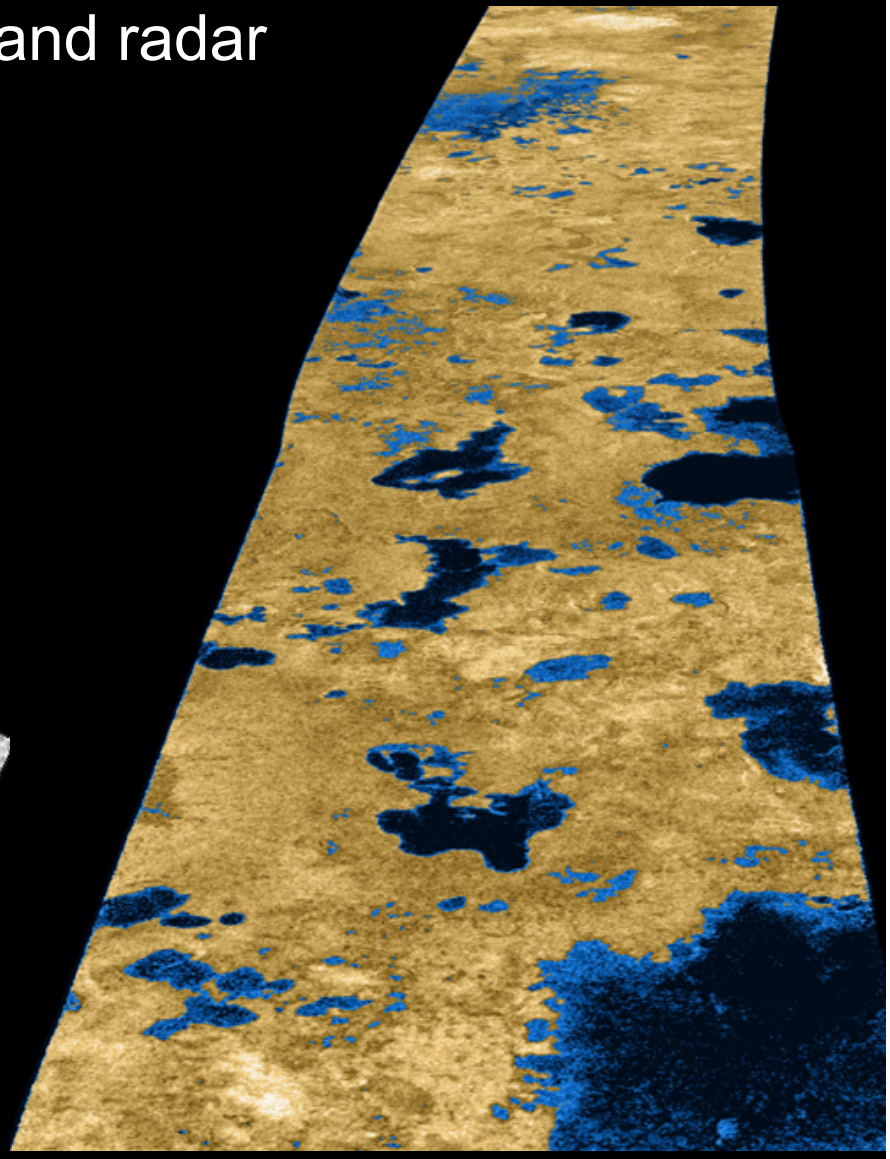
Saturn’s moon Enceladus
Cassini

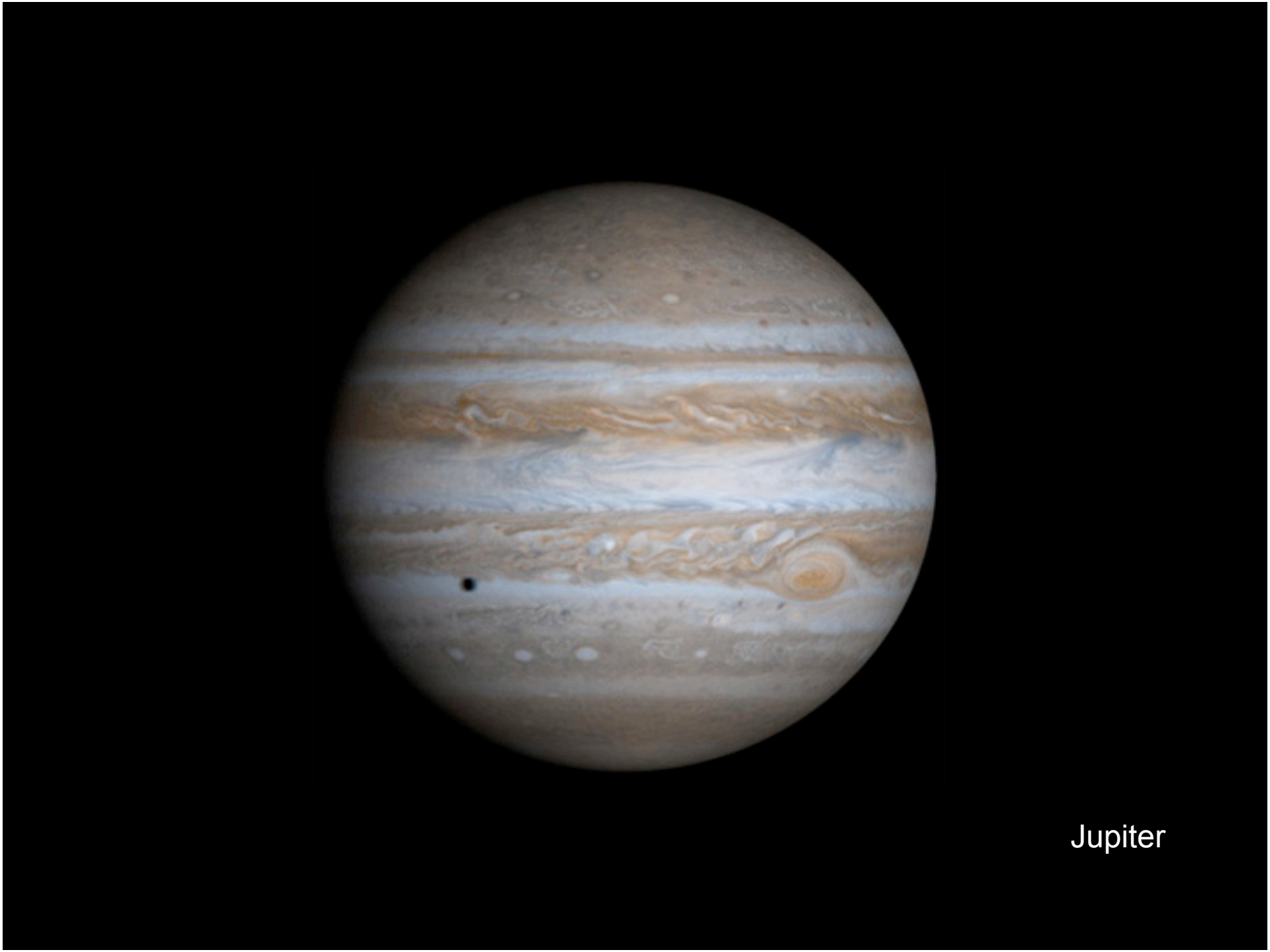
Saturn’s Moon Enceladus

Cassini

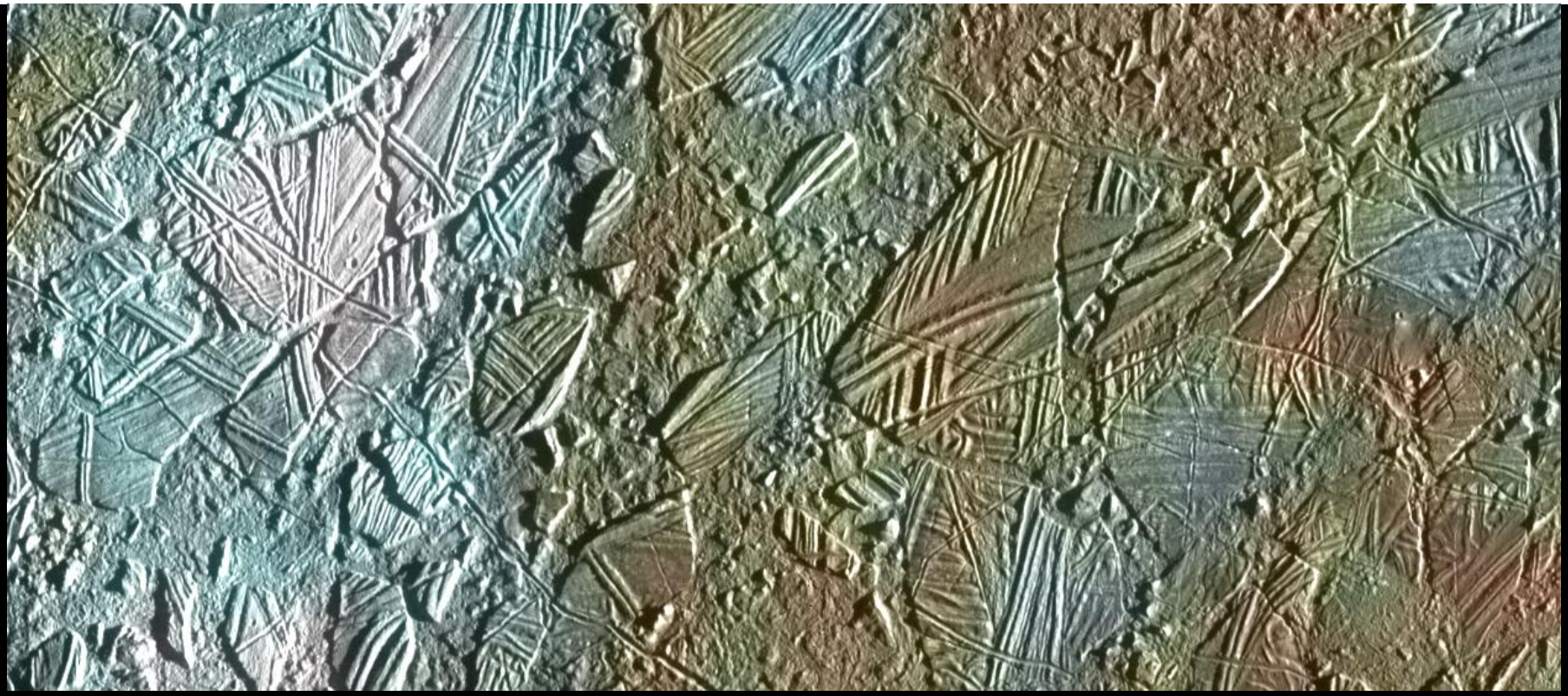
Cassini/Huygens studies hazy Titan with a probe and radar

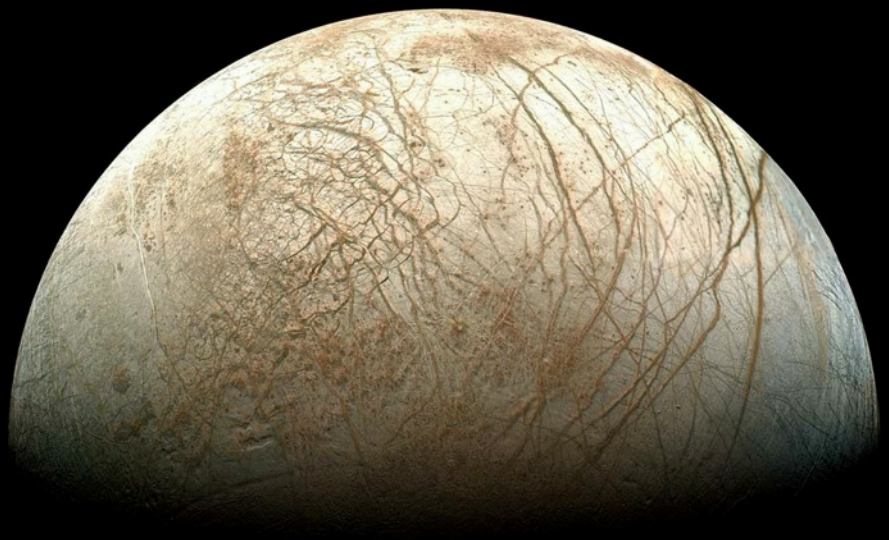


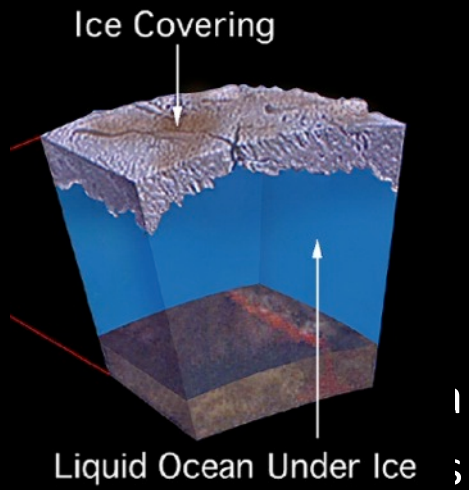


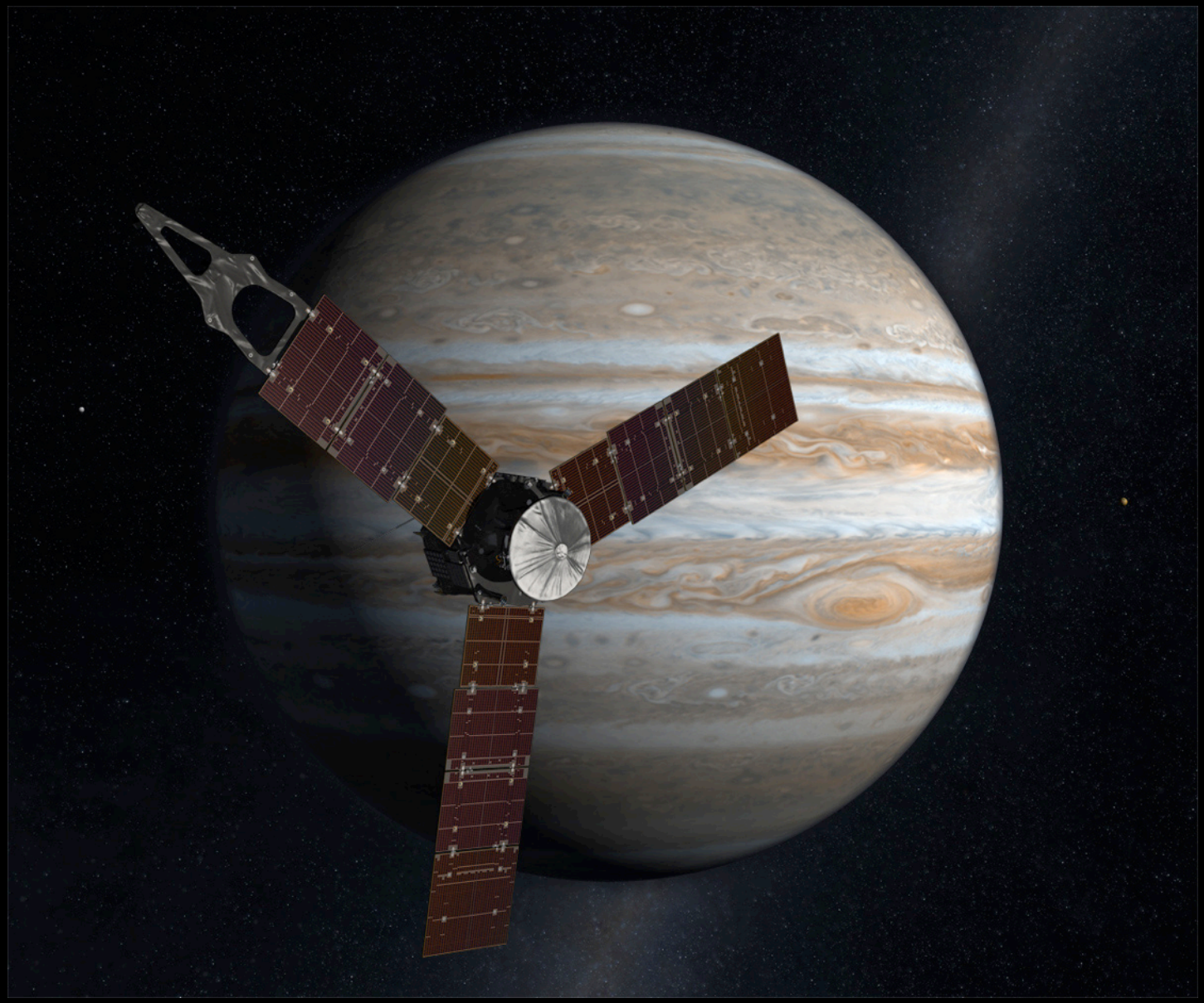


Jupiter

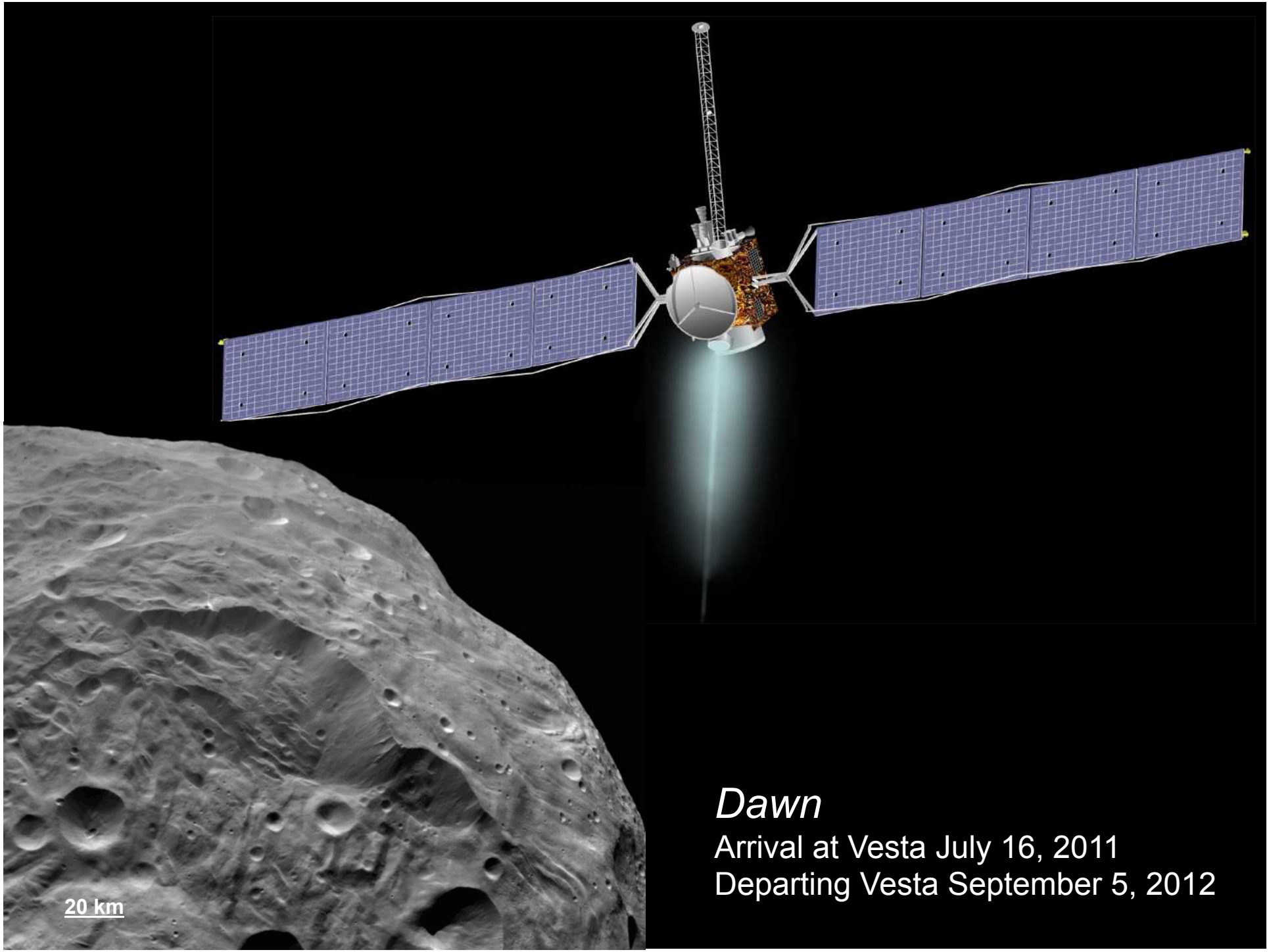


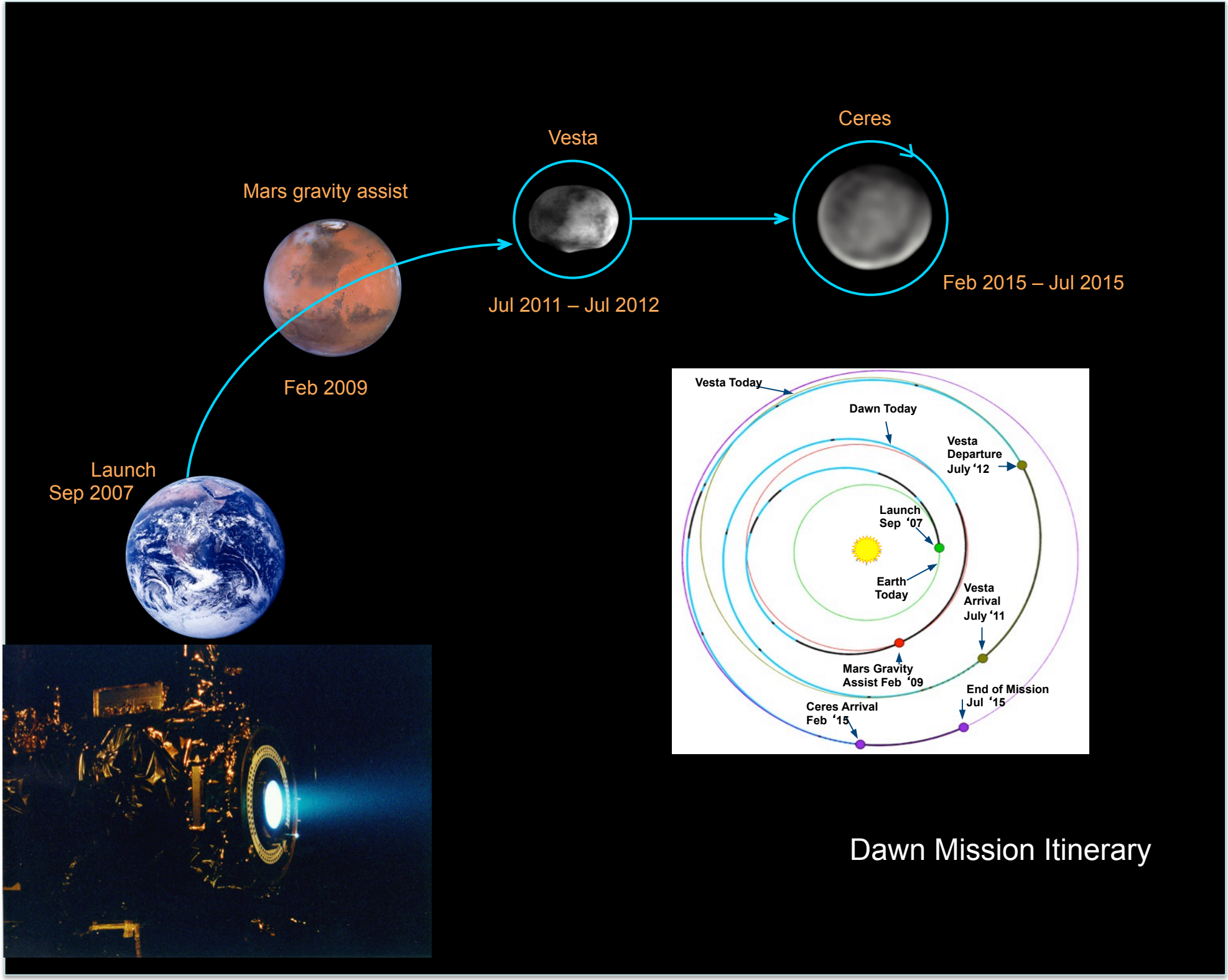



Ice Covering
Liquid Ocean Under Ice

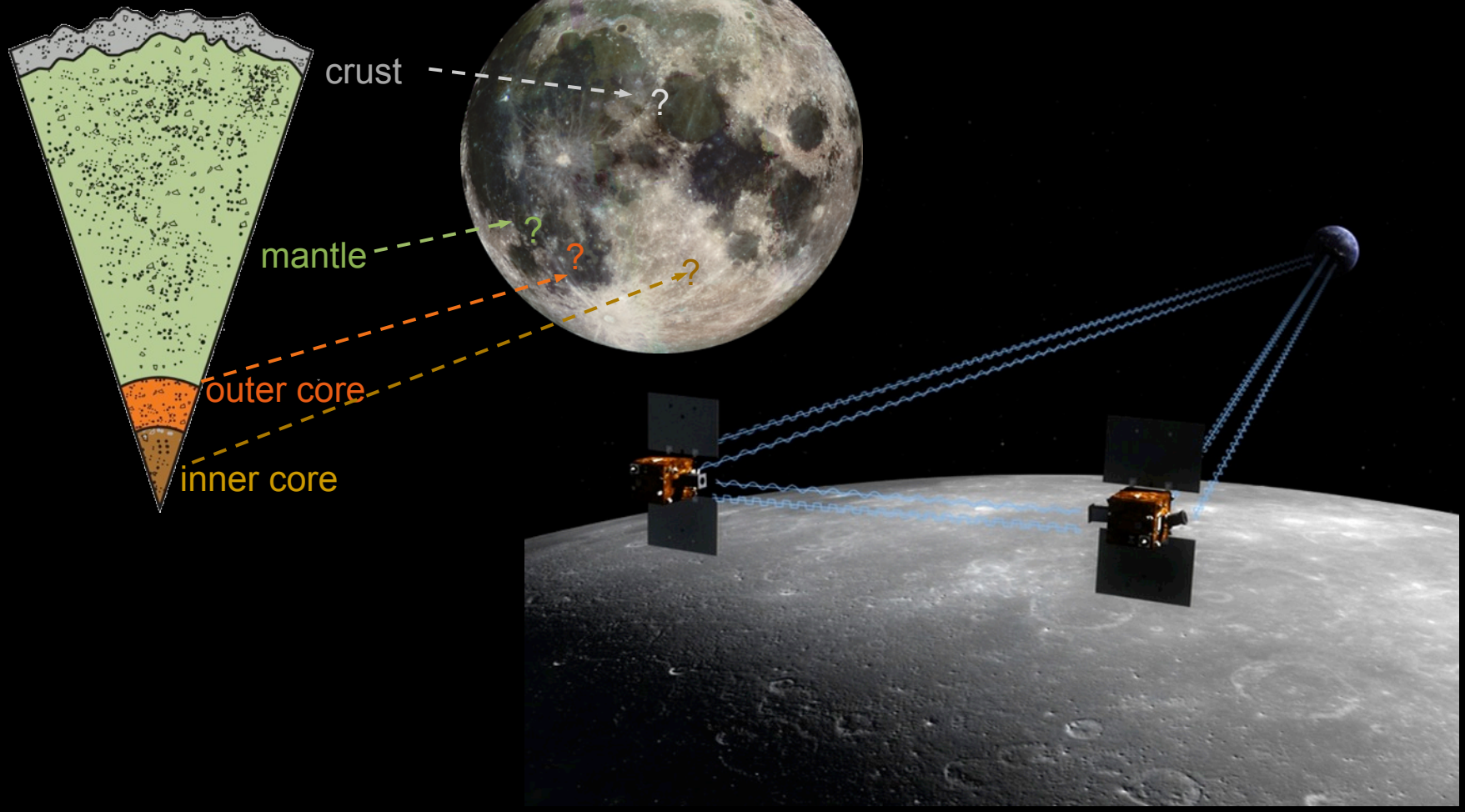


Juno
Arrival at Jupiter: July 2016


20 km
Dawn
Arrival at Vesta July 16, 2011
Departing Vesta September 5, 2012



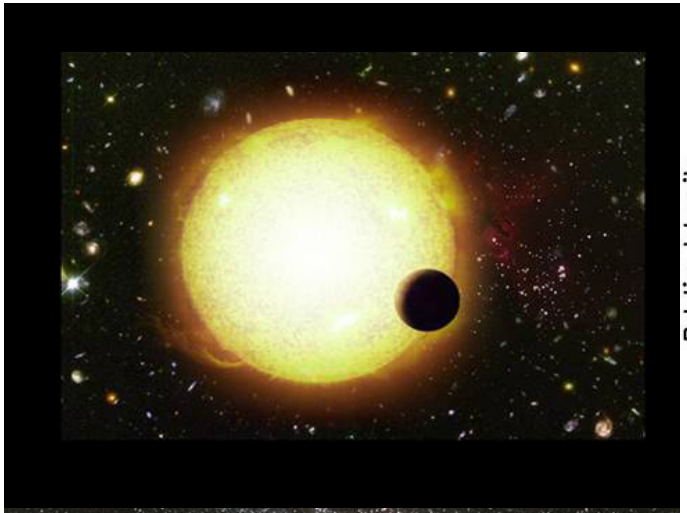
Dawn Mission Itinerary

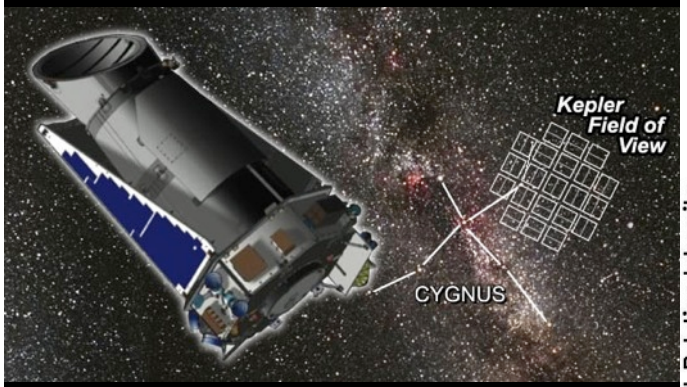


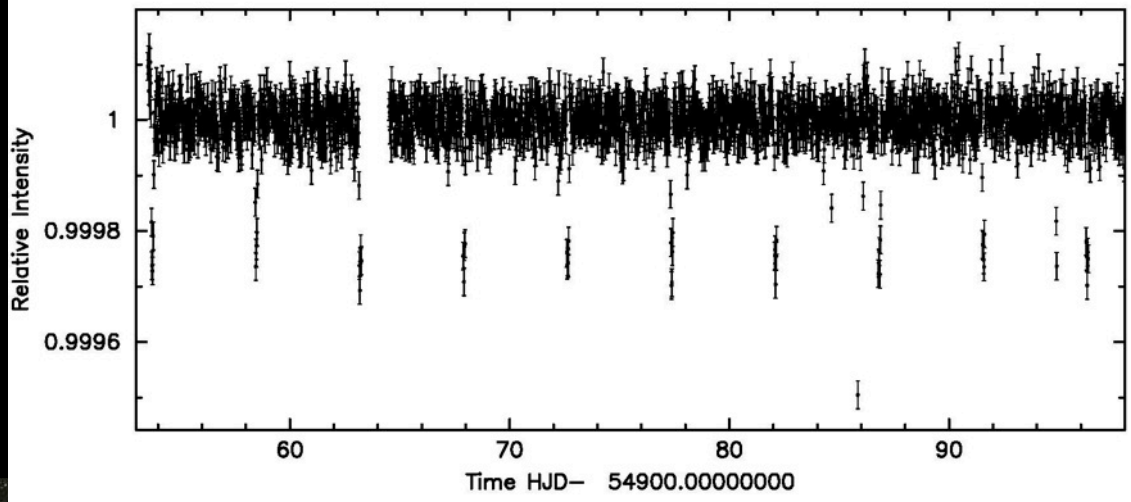
GRAIL

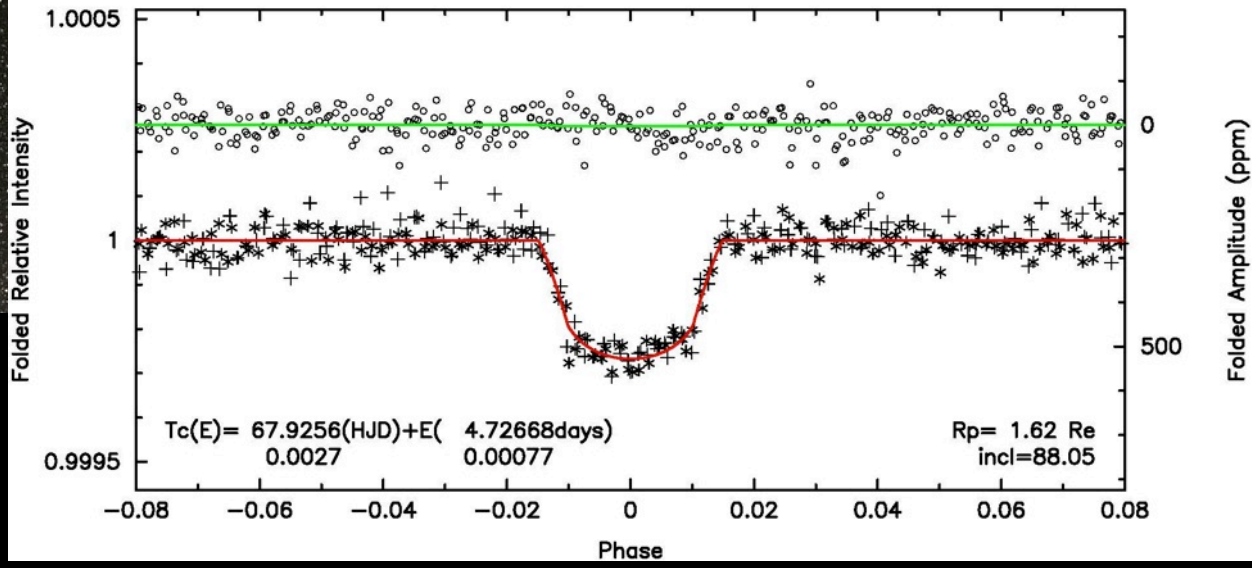
Advancing knowledge of thermal evolution of the moon

Kepler begins searching 100,000 stars for Earth-sized planets










Stars are a billion times brighter…


…than the planet
…hidden
in the glare.

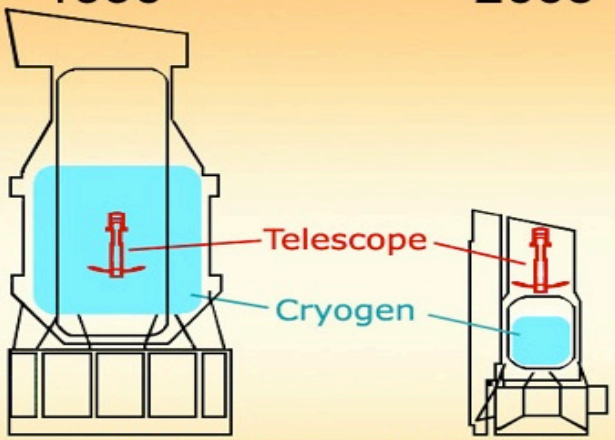

Like this firefly.

Innovation in space science mission design:

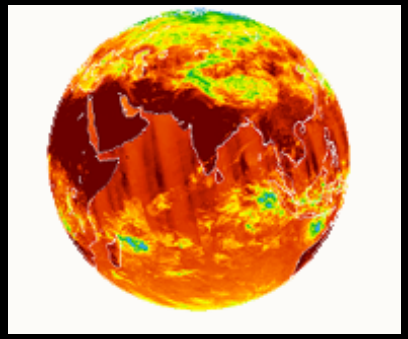
Spitzer: cost reduction by engineering innovation

SPITZER SPACE TELESCOPE

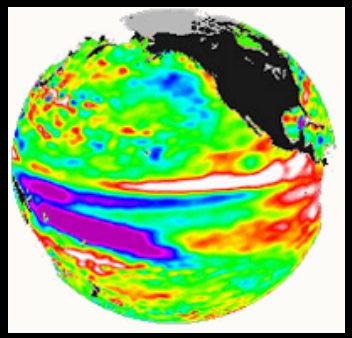
DESIGN CHANGES



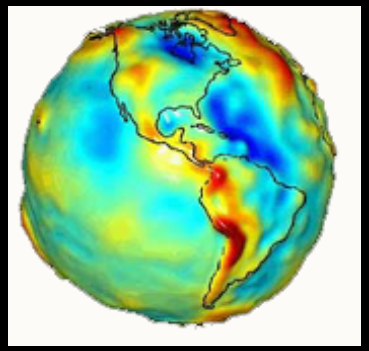
	COLD LAUNCH	WARM LAUNCH
Launch Mass	5700 kg	870 kg
Lifetime	5 years	5 years
Development Cost	~$2.2B	$0.67B
Launch Vehicle	Titan IV	Delta



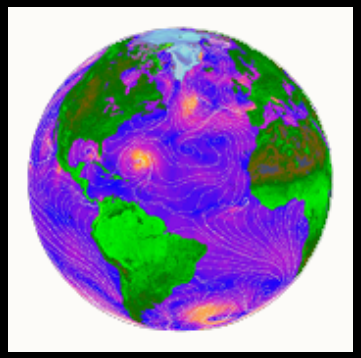
AIRS – atmospheric temperature



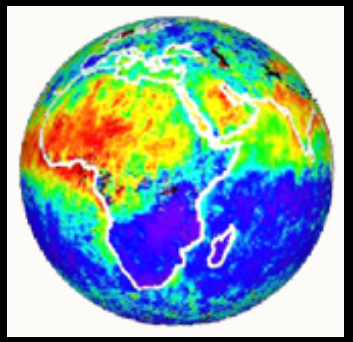
JASON – sea surface height



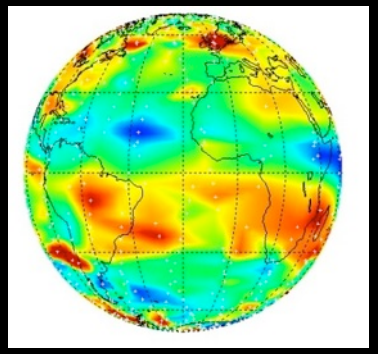
GRACE – gravity



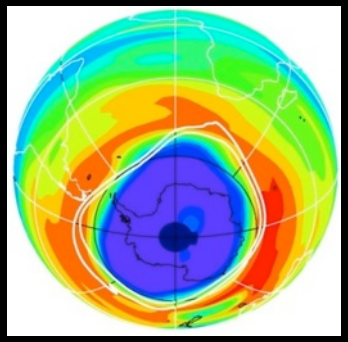
QUIKSCAT – wind



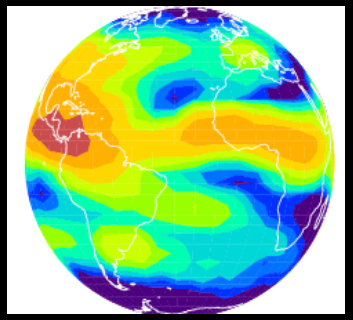
MISR - aerosols



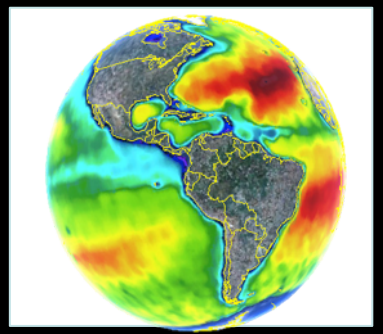
TES – trace gas



MLS – ozone layer



CLOUDSAT – water content

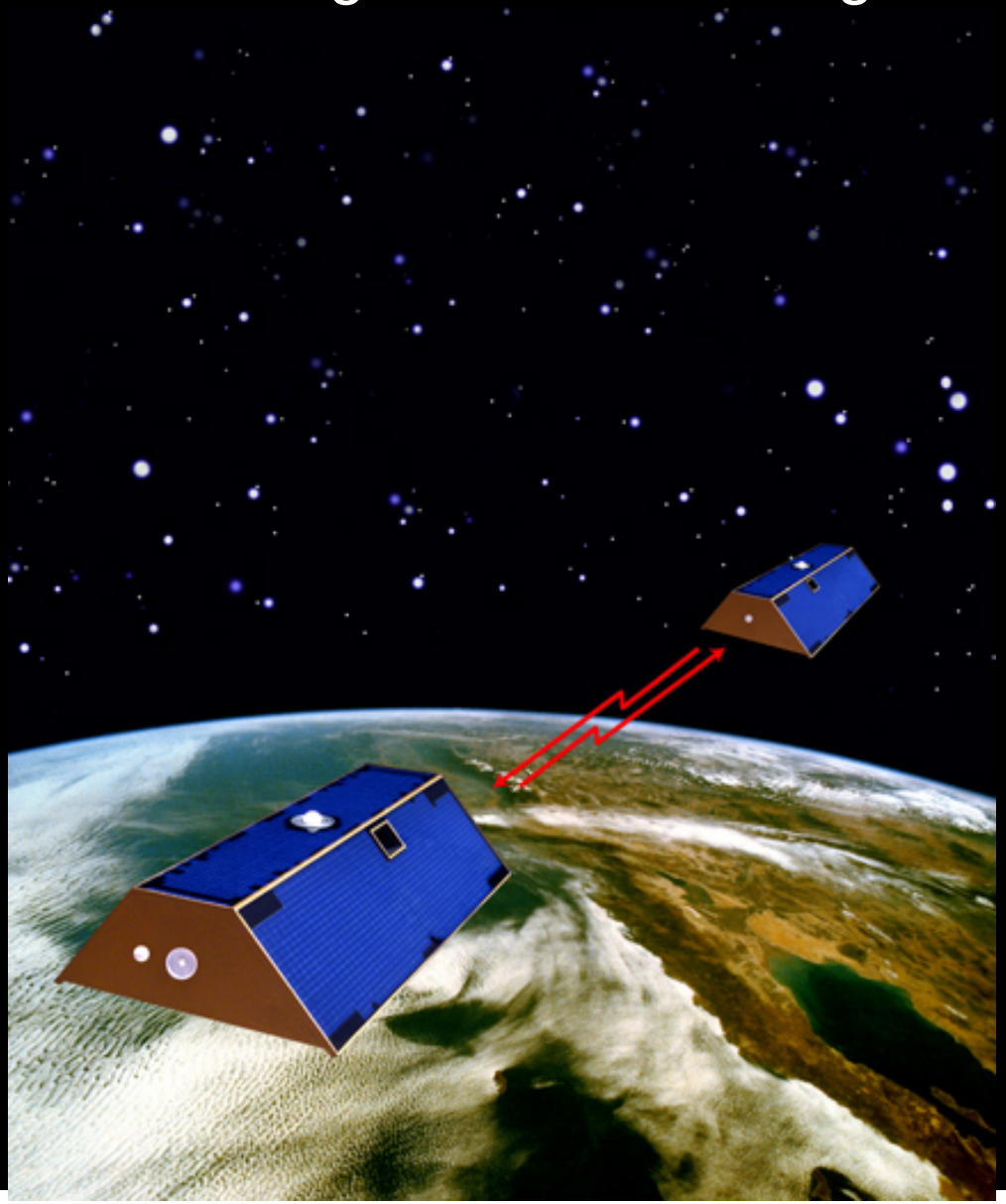


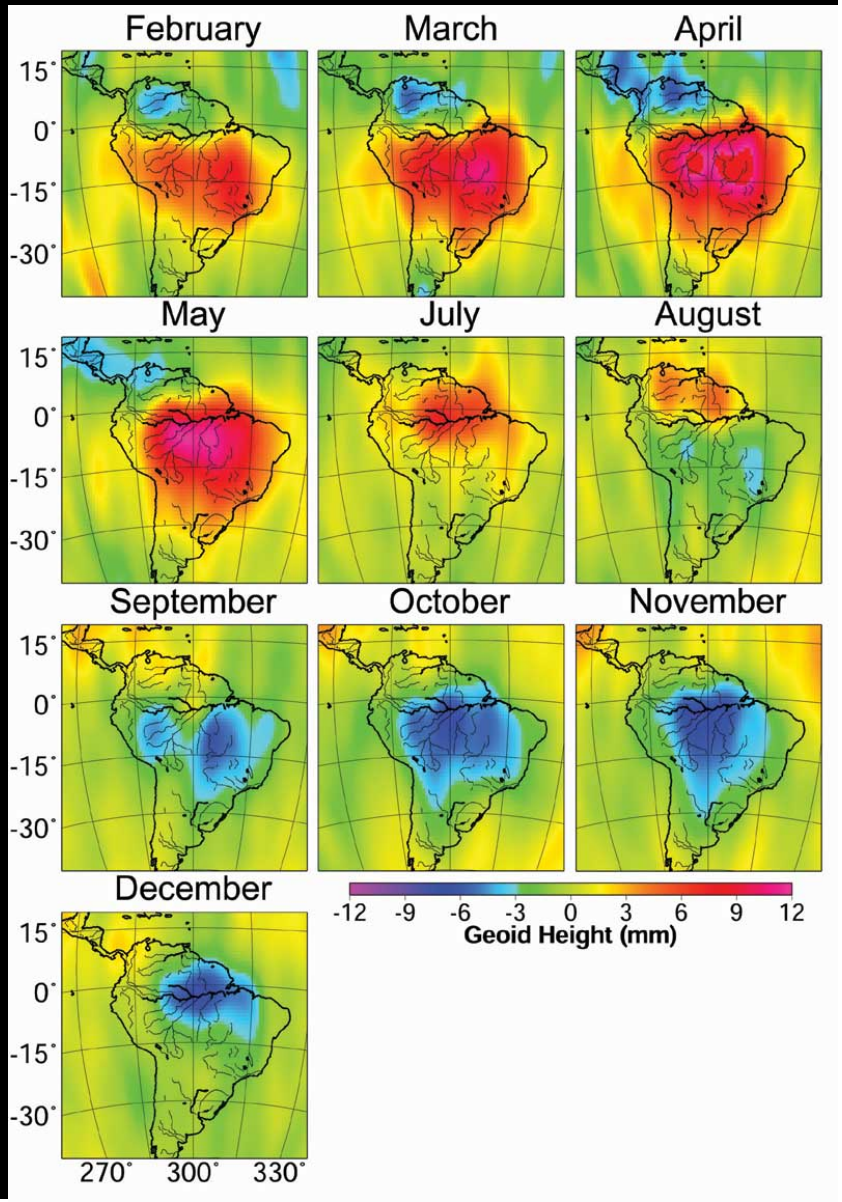
Aquarius - sea surface salinity

Multiple ways to look at a changing Earth

Innovative mission concept:

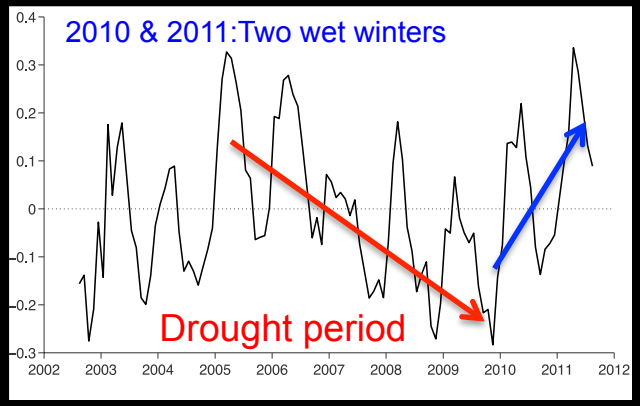
Gravity Recovery and Climate Experiment (GRACE) monitors seasonal groundwater changes





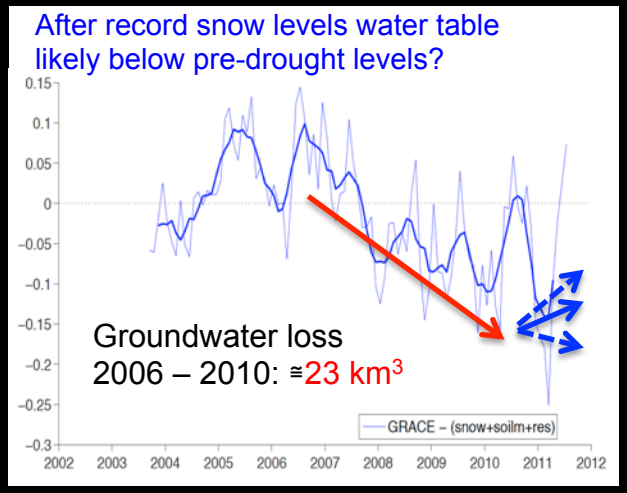
All Water Storage Components

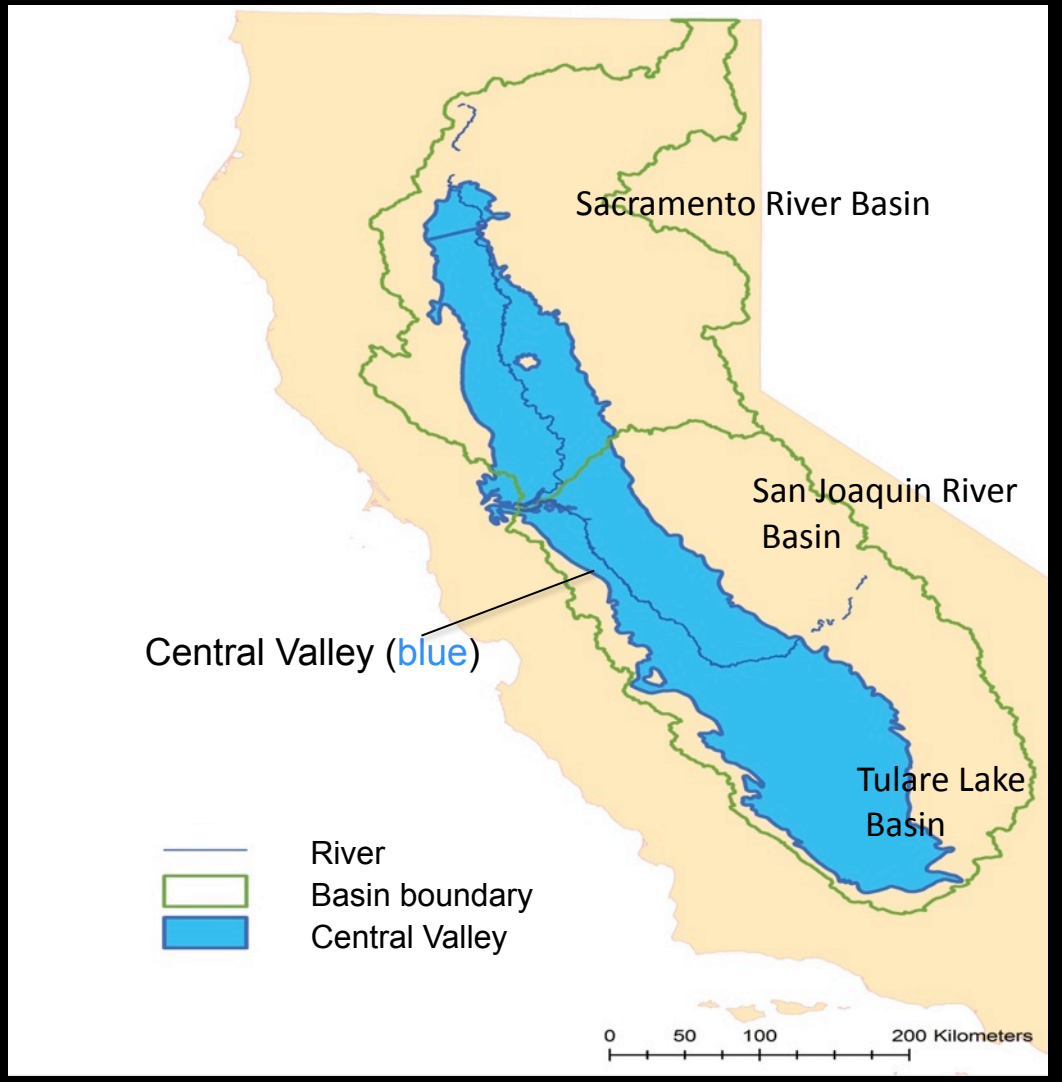
(incl. soil moisture, snow, reservoirs, and groundwater)



Groundwater Storage only

(soil moisture, snow, reservoirs subtracted)





Tracking Groundwater

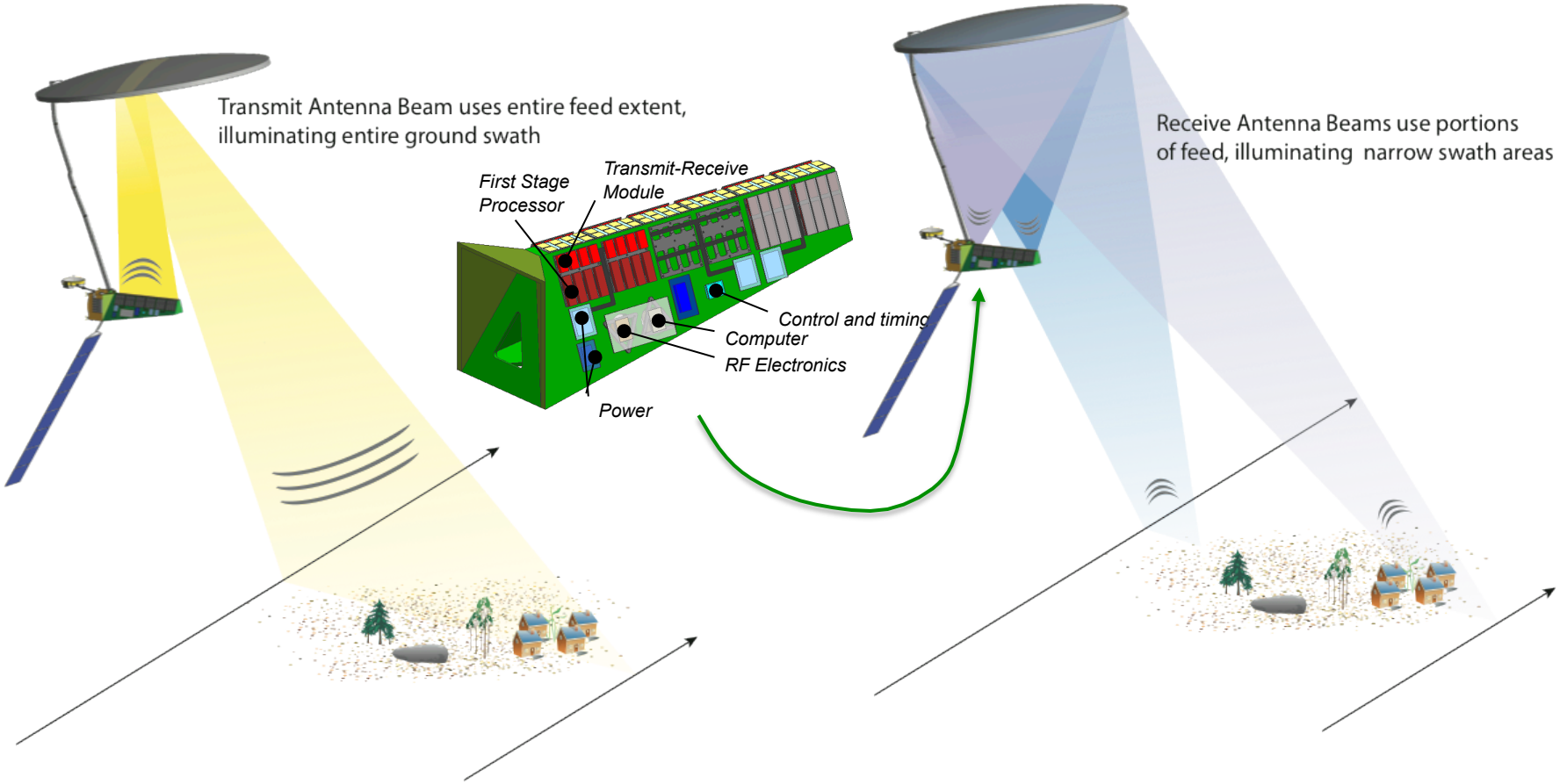
Grace

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

SweepSAR – First-of-a-kind Reflector-based DESDynI Radar

- **SweepSAR – Scan-on-Receive Radar**
  - **Transmit pulse over wide beam in elevation**
  - **Receive echo over narrow beam tracking echo with scanning receive beam**
  - **Can require multiple simultaneous receive beams to track multiple echoes**
- **Removes standard SAR performance limits using Digital Beamforming techniques on receive using reflector**
- **Achieves high area coverage at fine resolution and full polarization**

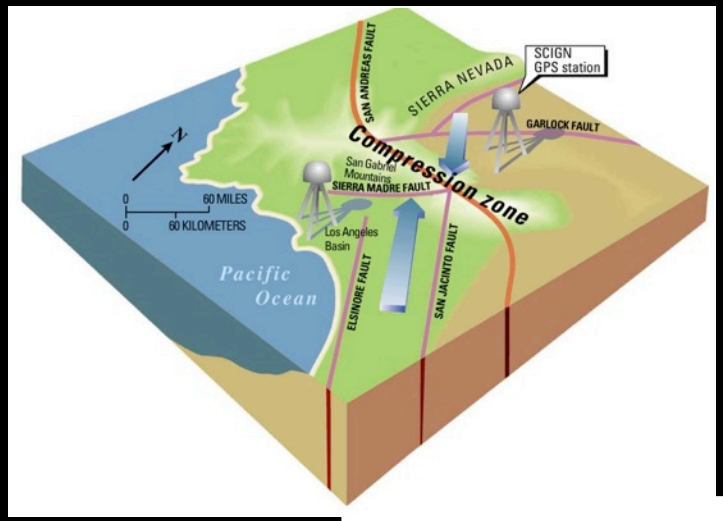


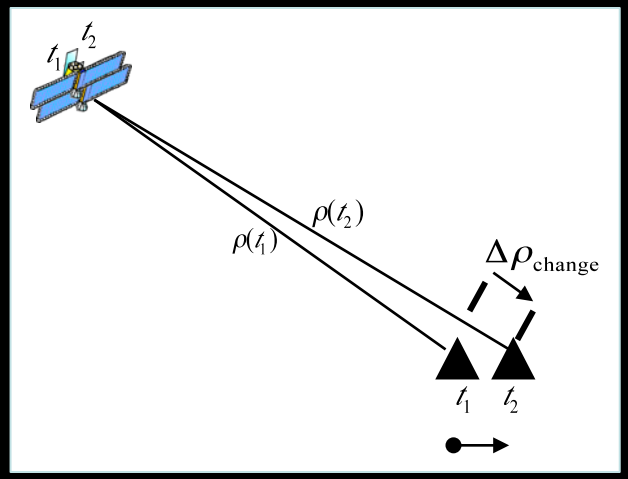

LA Basin
Shuttle Radar Topography Mission

National Aeronautics and Space Administration

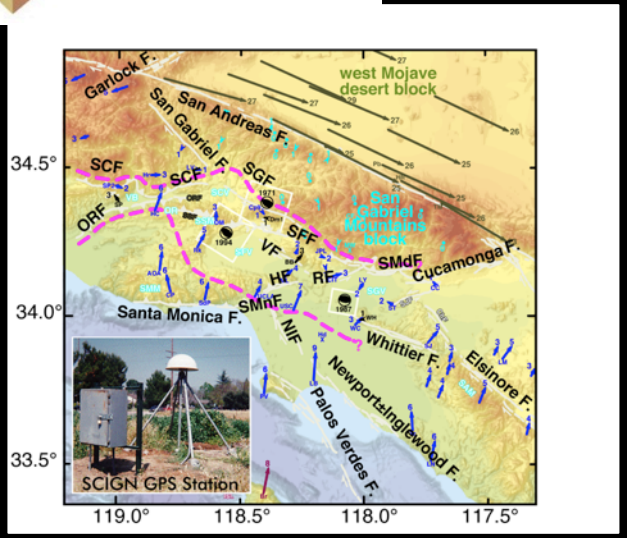
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

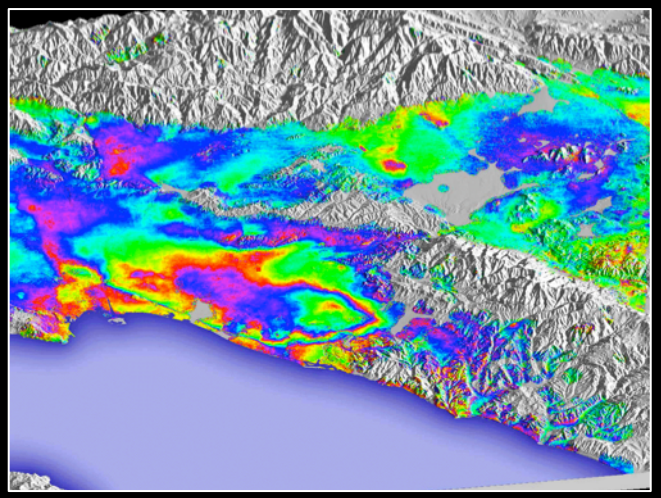
InSAR contributions to natural hazards assessment and disaster warnings



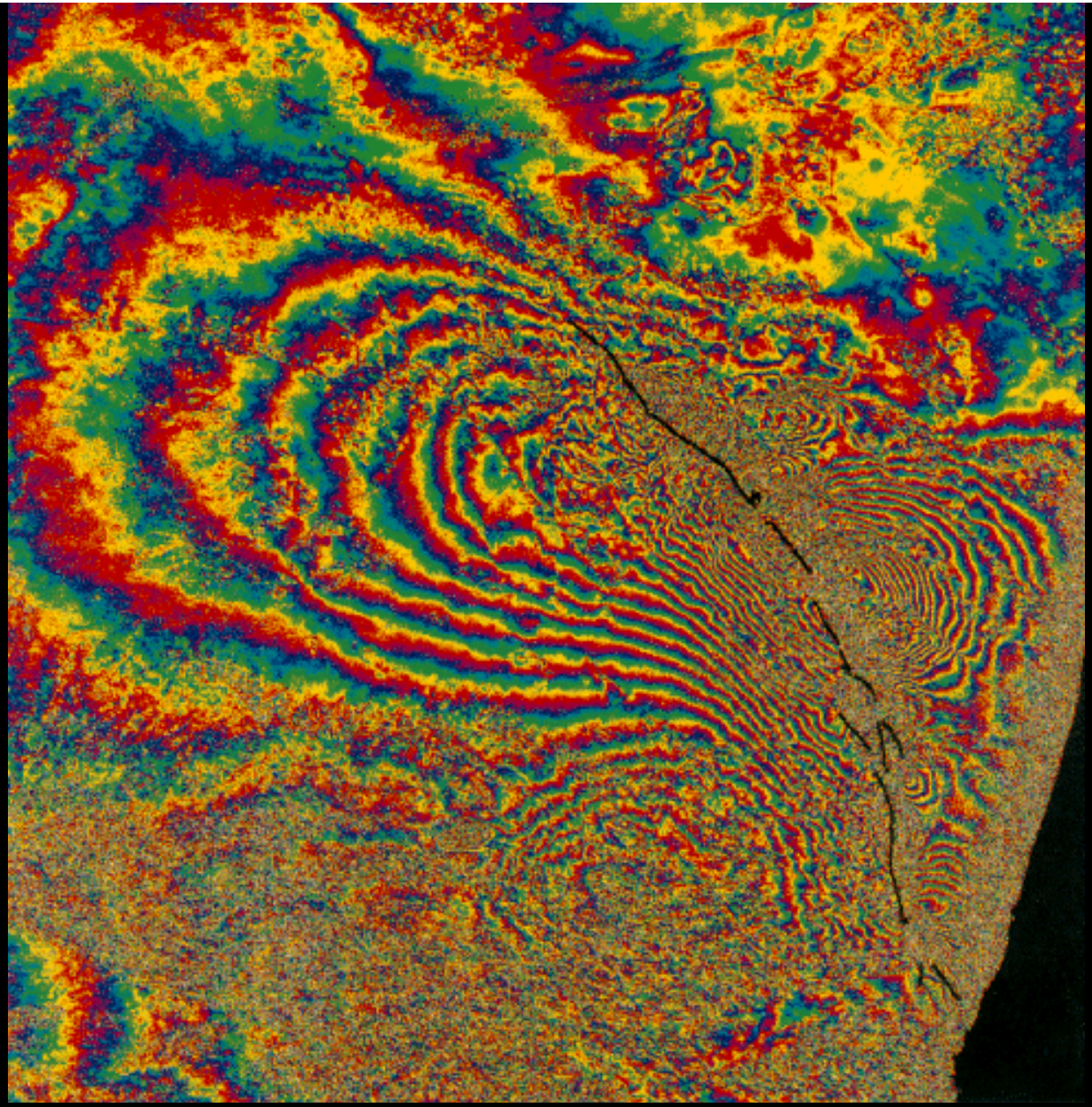


Repeat Pass Interferometry compares the phase of two successive images to estimate ground motion to mm precision



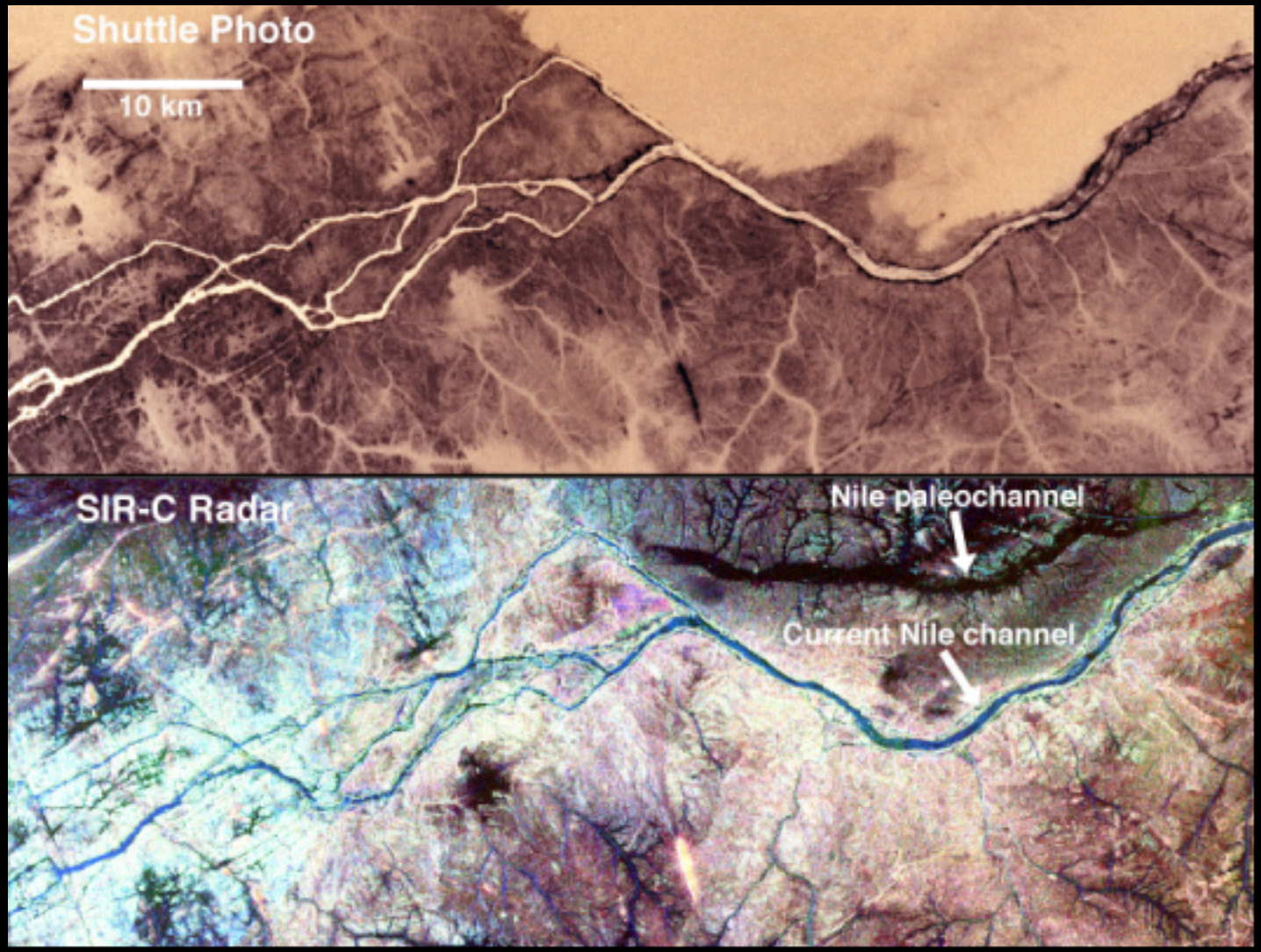


G. W. Bawden, W. Thatcher, R. S. Stein, K. W. Hudnut and G. Peltzer, Nature, 2001

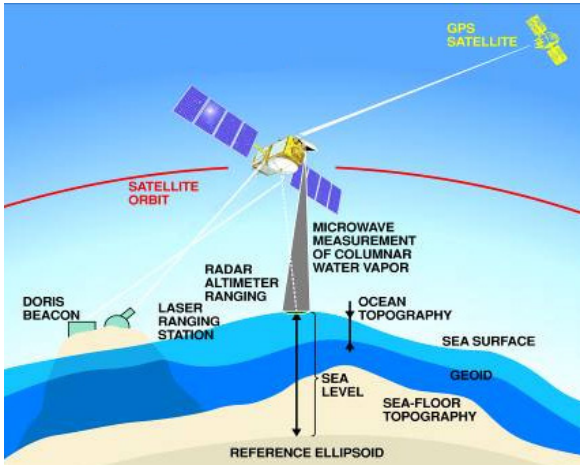


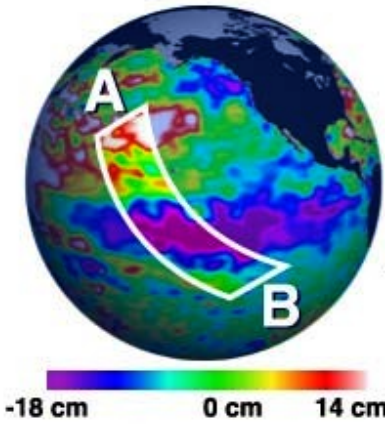
Studying solid Earth from space: Synthetic Aperture Radar image of Landers (CA) earthquake

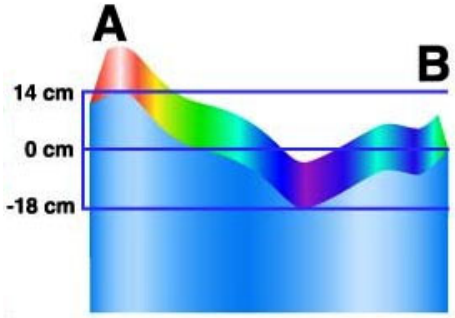
The ability of radar to see beneath sandy surfaces



Nile River
SIR-C

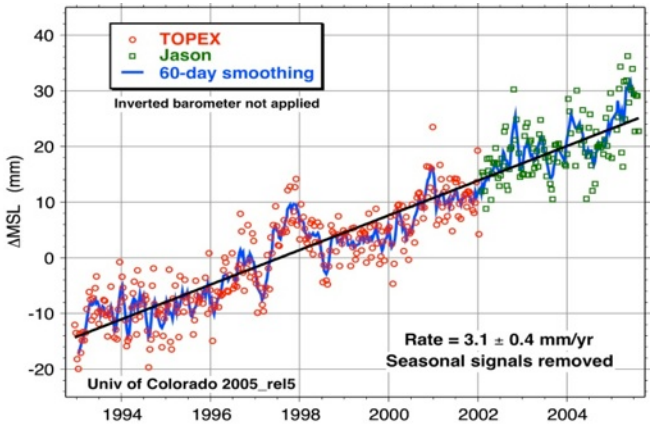






Radar altimeter measures sea surface height to an accuracy of <4 cm every 10 days

Considerable uncertainty exists in estimates of future sea level rise – particularly major changes in ice sheets



S. Nerem/U. Colorado

Ocean Surface Topography Mission (OSTM)

“Far better is it to dare mighty things, to win glorious triumphs—even though checkered by failure—than to rank with those poor spirits who neither enjoy much nor suffer much; because they live in the gray twilight that knows not of victory, nor defeat.”

-Theodore Roosevelt